SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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California Water Pollution Control—Rawn and Bacon

Los Angeles Facilities—Theroux

Radioactive Water Pollutants—Tsivoglou and Towne

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FEBRUARY, 1957—VOL. 29, No. 2

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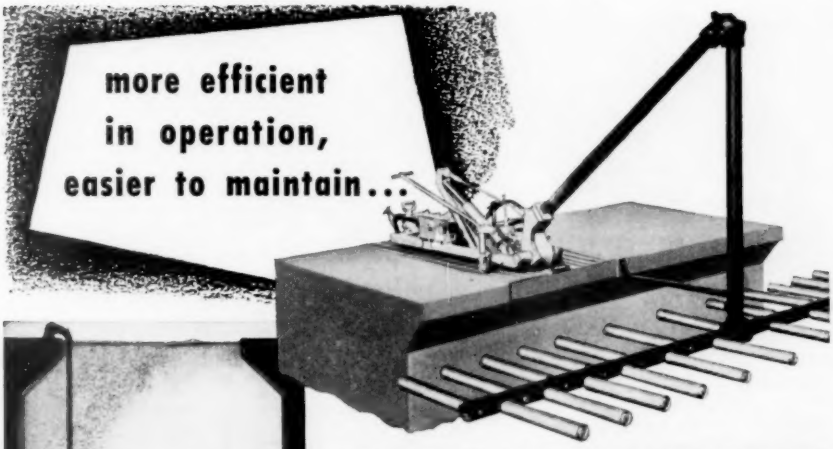

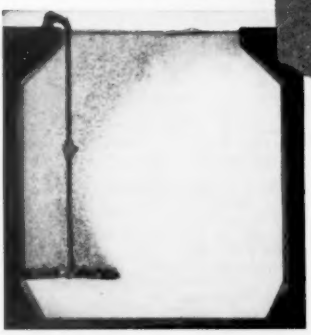

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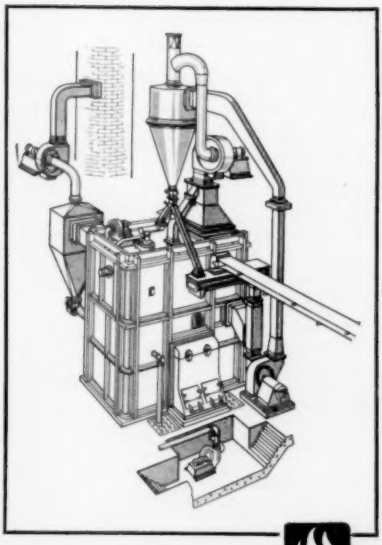

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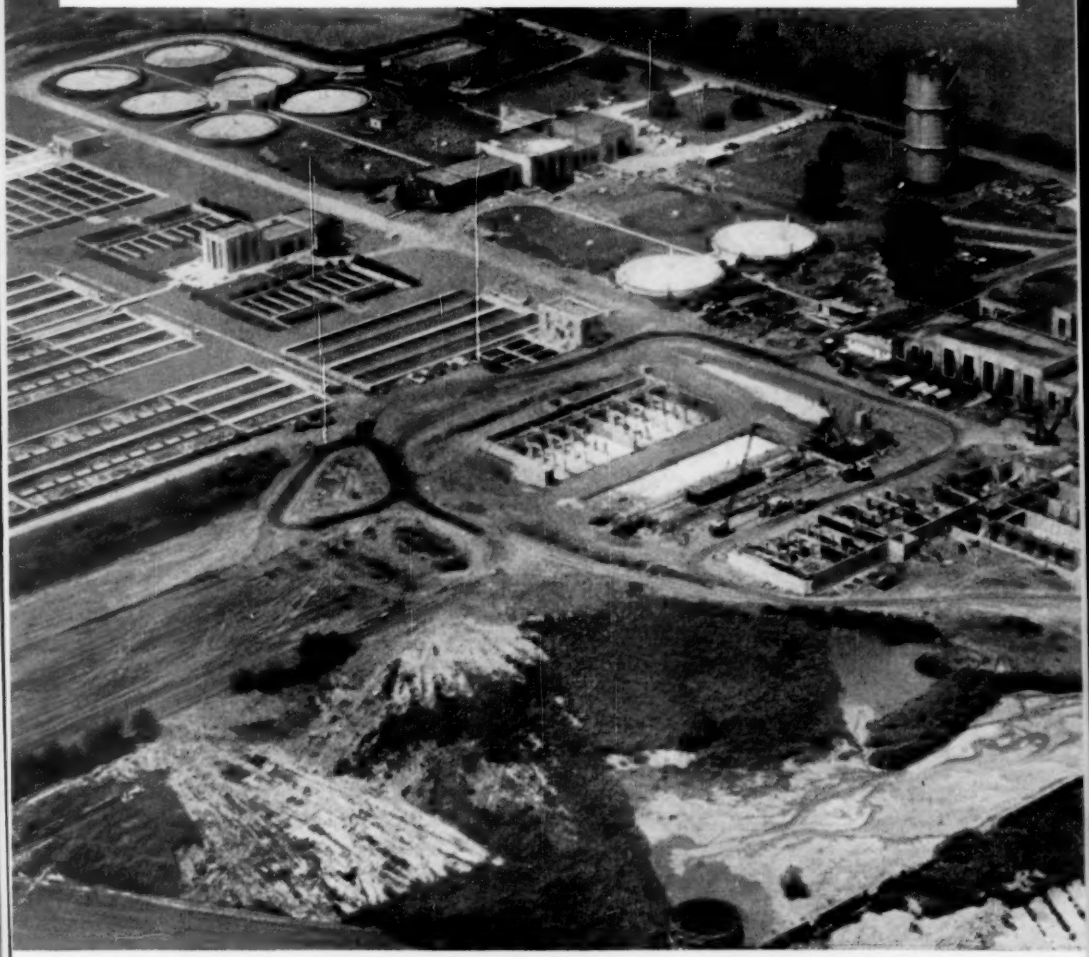

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Association	*Place*	*Time*
Texas Water and Sewage Works Assn.	Texas A & M College College Station, Tex.	Mar. 3–8, 1957
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 13–15, 1957
Arkansas Water & Sewage Conf.	Marion Hotel Little Rock, Ark.	Mar. 18–20, 1957
Louisiana Conference on Water Supply and Sewerage	Univ. of Louisiana Baton Rouge, La.	Mar. 20–22, 1957
Virginia Industrial Wastes and Sewage Works Assn.	Williamsburg Lodge Williamsburg, Va.	Mar. 21–22, 1957
Montana Sewage and Industrial Wastes Assn.	Rainbow Hotel Great Falls, Mont.	Apr. 4, 1957
Arizona Sewage and Water Works Assn.	Maricopa Inn Mesa, Ariz.	Apr. 4–6, 1957
Kansas Sewage and Industrial Wastes Assn.	Broadview Hotel Wichita, Kans.	Apr. 10–12, 1957
California Sewage and Industrial Wastes Assn.	San Diego, Calif.	May 1–4, 1957
Maryland-Delaware Water and Sewage Assn.	Commander Hotel Ocean City, Md.	May 22–24, 1957
Institute of Sewage Purification	Margate, England	June 17–21, 1957
Ohio Sewage and Industrial Wastes Treatment Conf.	Miami Hotel Dayton, Ohio	June 19–21, 1957
Central States Sewage and Industrial Wastes Assn.	Sherman Hotel Chicago, Ill.	June 26–28, 1957

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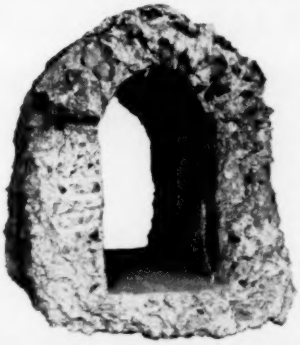

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CONCRETE FACT — This is a section of the Roman aqueduct between Eiffel and Cologne, built in 80 A.D., in use continuously until 1928. A natural cement occurring along the Rhine between Cologne and Coblenz was used by Roman army engineers in building the aqueduct. (Photo, courtesy Smithsonian Institute, Washington, D. C.)

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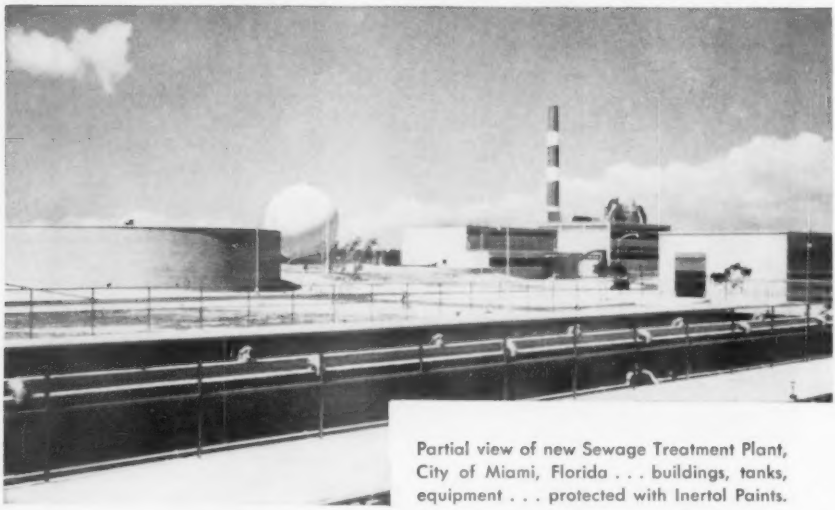

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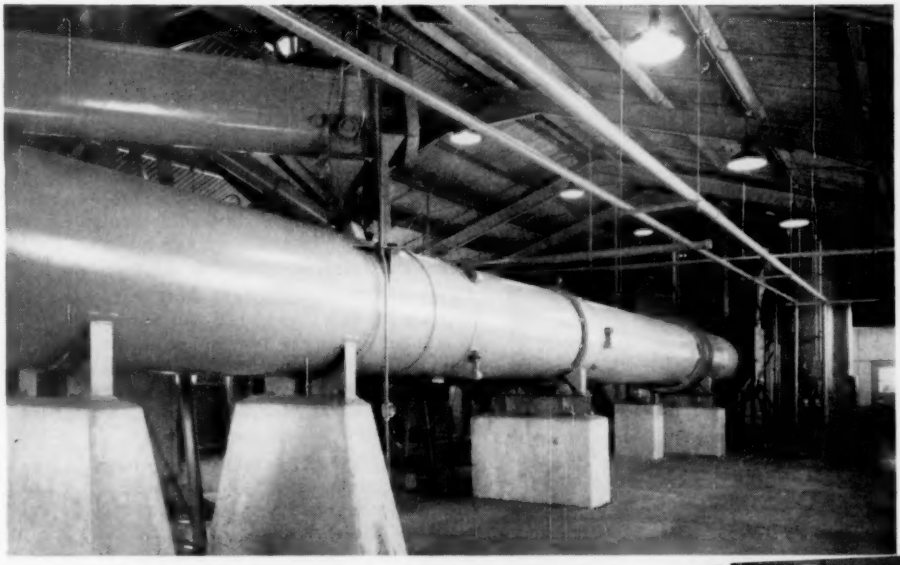
FOR Corpus Christi



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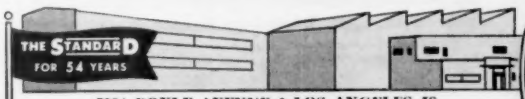

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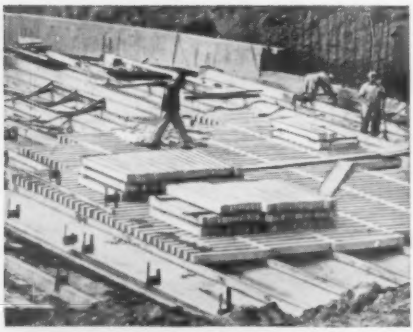

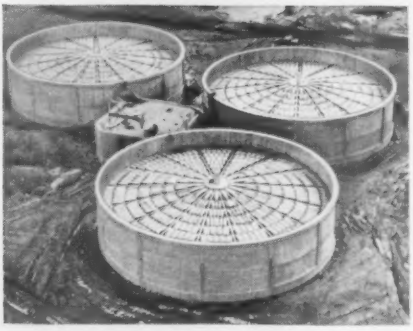

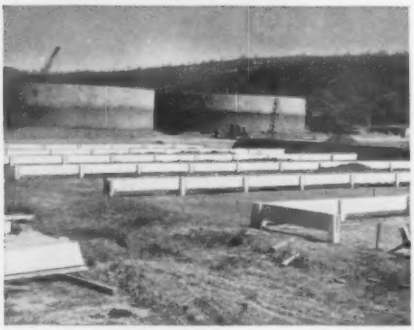

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DIGESTER COVERS in the East Providence plant (second photo) are 2-in. thick, tongue-and-groove precast concrete planks. Concrete resists rot in a damp atmosphere, assures positive closure.

Covers for the digester tanks of the Benton Harbor-St. Joseph, Mich. Sewage Treatment Plant (third photo) are short slabs of precast concrete that rest on purlins connecting radial girders. Crevices between slabs are calked with mastic. Covers are 80 ft. in diameter.

SLUDGE BED PLANKS AND POSTS in Elmira, N. Y. Sewage Treatment Plant are precast concrete units (bottom photo). Durable precast concrete units withstand a lifetime of weathering and freeze-thaw cycles in such installations.

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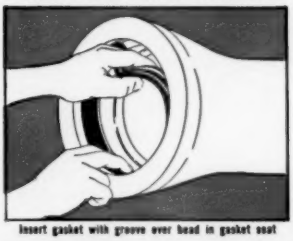
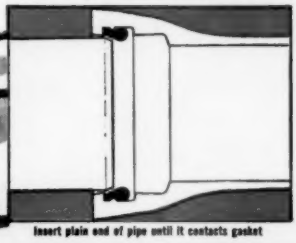
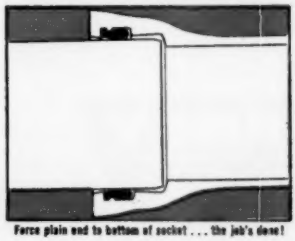


Insert gasket with groove over bead in gasket seat

Wipe a film of special lubricant over inside of gasket

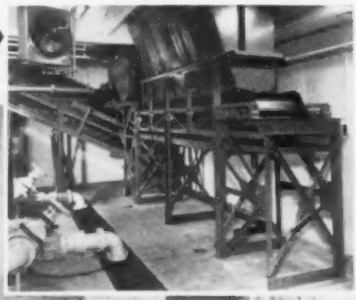


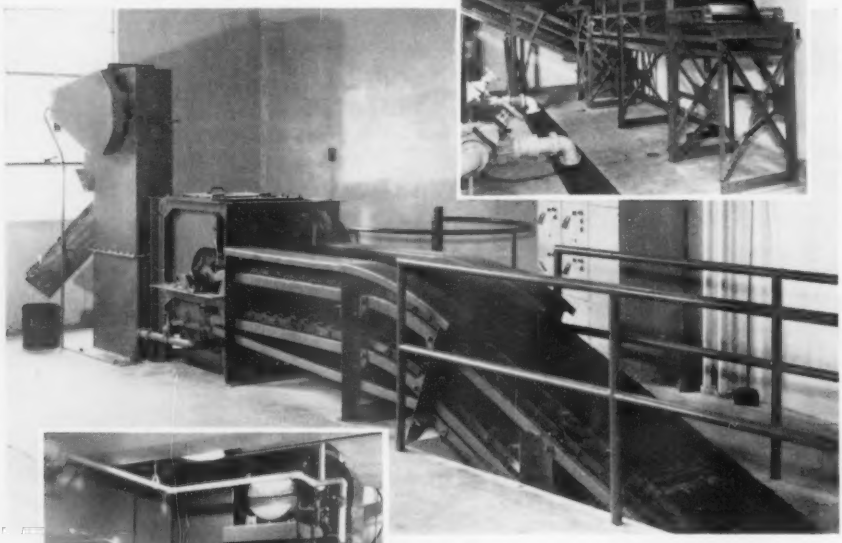
Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket . . . the job's done!

Trucks dump garbage into this hopper. A slow-moving apron conveyor discharges onto the faster-moving apron conveyor, thinning out the material.





This apron conveyor drops the garbage into a Jeffrey Type B grinder. The bucket elevator at the left discharges grit from the washer seen below.

From the grinder the garbage passes into the washer where grit is removed. The organic slurry overflows into the slurry tank and is pumped to the digesters.

JEFFREY

recommends dual garbage-sewage disposal for low operating costs

Garbage can be economically disposed of with sewage solids. Jeffrey sanitation engineers have found that garbage solids can be ground and pumped directly to digesters. Grit is removed first, of course. That is the system illustrated here at the new treatment plant in Kokomo, Ind.

For help on any treatment plant problem, write to The Jeffrey Manufacturing Company, Columbus 16, Ohio.

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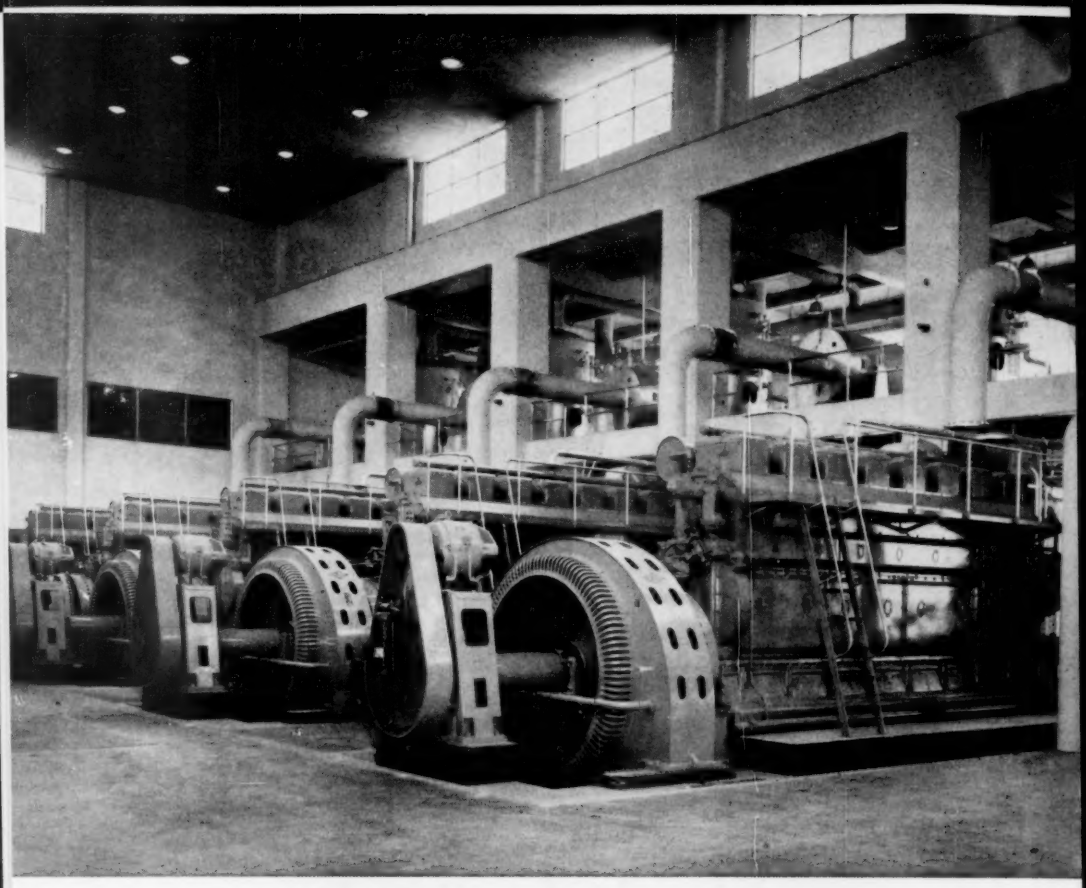

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If you would like a reprint of "Hyperion's Six Years of Operation," an interesting article about the plant and its many maintenance innovations, please write to Section W63, Worthington Corporation, Harrison, N. J. Ask for Bulletin RP-928. In Canada: Worthington (Canada) 1955, Ltd., Toronto, Ont.

WORTHINGTON

It looks like a swank cabana club, but this impressive establishment is the new sewage treatment plant at Coral Gables.

Beauty Comes to Sewage Treatment

Murals adorn the new sewage treatment plant on the main street of Coral Gables, Florida

How times change! Until recently, you would normally expect to find the sewage treatment plant on the wrong side of the tracks, hidden away in an isolated spot. Today, however, proper equipment positively controls odors, and attractive landscaping provides a pleasing appearance. As a result, cities can now build in the most practical location. And often a plant that's close-in saves miles of costly sewers.

Coral Gables selected its plant site on Ponce de Leon Boulevard, the city's main thoroughfare. A pleasant and attractive sewage treatment plant was constructed, and the digesters equipped with P.F.T. Floating Covers for efficient "controlled digestion." Then the city commissioned well-known artist John St. John to beautify the walls of the digestion tanks with historical murals. And so, in a state where nothing seems surprising, the sparkling new sewage treatment plant at Coral Gables has become a magnificent civic showplace! Write today for additional information, including full color illustrations.

Design of plant by *Smith and Gillespie, Consulting Engineers of Jacksonville, Florida.* Direction of overall sewer project by *M. B. Garris, Consulting Engineer of Miami.*

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 29 | **February, 1957** | **Number 2**

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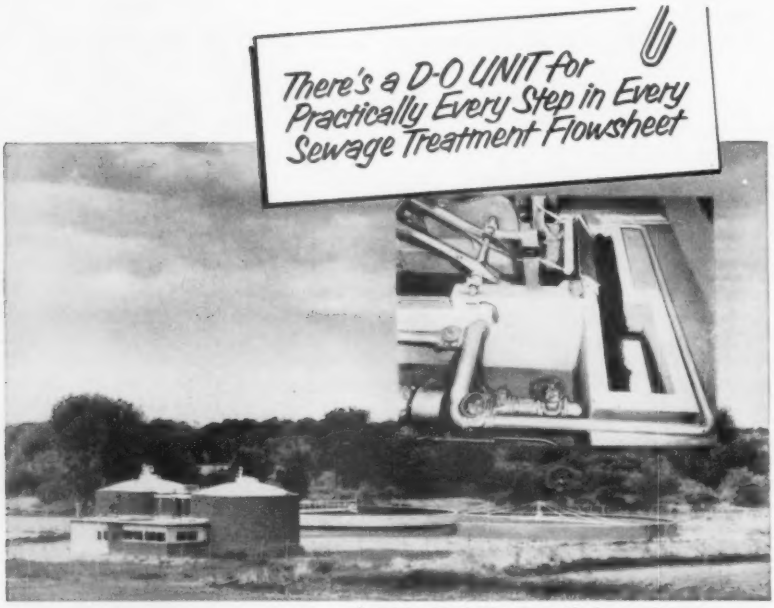

General view of the plant. Inset, closeup of Bar Screen and Disintegrator.
Consulting Engineers: Ripple & Howe, Denver, Colorado.

DORRCO BAR SCREEN — SULZER DISINTEGRATOR

Simplifies Screenings in Municipal and Industrial Waste Treatment Plant . . . Biofiltration Flowsheet

The North Washington Sanitation District sewage treatment plant near Welby, Colorado takes care of both domestic and packing house wastes.

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Sewage Works

INVESTIGATION OF PRIMARY LAGOON TREATMENT AT MOJAVE, CALIFORNIA *

By Robert C. Merz, John C. Merrell, and Ralph Stone

Respectively, Professor of Civil Engineering and Research Associates, University of Southern California, Los Angeles, Calif.

One of the several principal studies carried on under a research contract between the California State Water Pollution Control Board and the University of Southern California concerned reclamation of a raw sewage lagoon effluent at Mojave, Calif. It is this study that is reported herein.

The study had a twofold purpose: (a) provide a Marine air base with a suitable, economical irrigation water for use on grasses at the air station, particularly along the edges of the flight strips where wind erosion of sand had resulted in damage to jet engines; and (b) demonstrate that the raw sewage lagoon, when well designed and operated, can be an adequate means of sewage treatment for the small desert community. The investigation was a cooperative effort on the part of the Mojave Public Utility District, the Public Works Office of the U. S. Navy, the Sanitary Engineering Laboratory of the 11th Naval District at San Diego, and representatives of the Marine Corps Auxiliary Air Station at Mojave.

Test Lagoon Layout

The relative sizes and positions of the various units of the entire test installation are shown in Figure 1. The two small raw sewage lagoons, known as the east and west basins, have been in operation for more than eight years. Each is 46 ft. wide by 143 ft. long. Since they have been in continuous use, their depths have not been accurately determined; however, it is believed that the maximum depth is 10 ft. and the average depth 4 ft.

A new primary lagoon, known as the new basin and having surface dimensions of 143 ft. by 175 ft. and an average depth of about 9 ft., was specially constructed for test purposes adjacent to the existing east basin. By "primary lagoon" is meant a basin designed to receive raw sewage and constructed of adequate depth to insure proper diffusion, temperature control, and beneficial mixing of the lagoon contents. The east basin normally operated in series with the new basin, and can thus be termed a secondary lagoon or oxidation pond.

The east and west basins are constructed with earthen dikes that have a freeboard of 2 to 3 ft. The surface area of each is 0.15 acres. Raw sewage is introduced into these basins by means of 12-in. diameter vitrified clay pipes submerged approximately 6 ft. below the water surface. Similar type outlet pipes are located at the opposite ends of the basins, thus enabling the effluent to be withdrawn and discharged into a ditch. A small ditch carries the overflow waste water from both the east and west basins to a pasture, where

* Presented at 1956 Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Los Angeles, Calif.; Oct. 8–11, 1956.

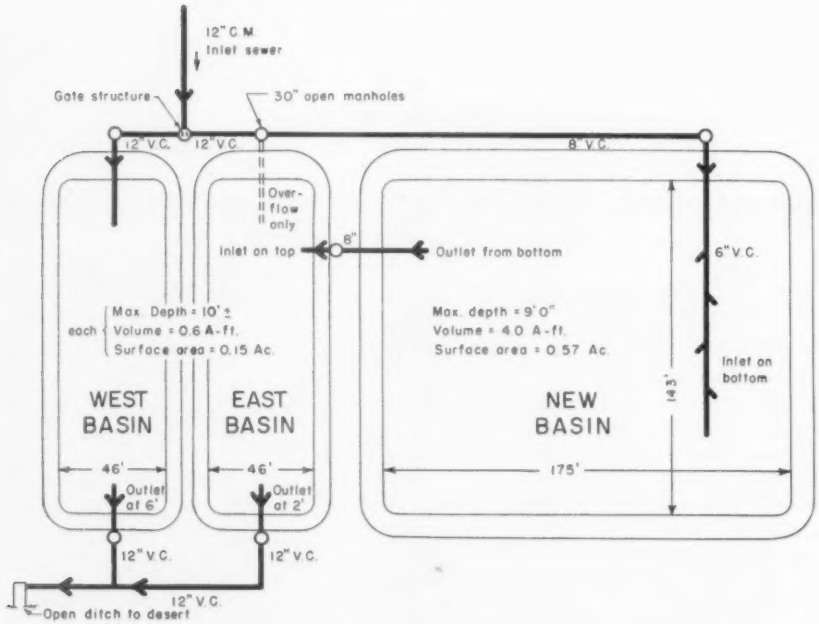

FIGURE 1.—Schematic diagram for raw sewage lagoon treatment at Mojave, Calif.

the effluent is employed for irrigation of approximately 25 acres. The desert soil, which formerly supported only desert plants, has been successfully planted with Bermuda grass, and the pasture maintains a herd of about 50 beef cattle.

The new basin was constructed by employing two bulldozers and a scraper. The bottom has a slight slope. The surface area is 0.57 acres. An 8-in. diameter vitrified clay pipe was used to bypass a portion of the raw sewage into a 6-in. diameter vitrified clay pipe entering the new basin. This outfall pipe is located approximately 40 ft. from the east bank and at the bottom.

The effluent from this primary lagoon discharges through a submerged outlet pipe located in the northwest section into the existing east basin, which is used as a secondary lagoon or oxidation pond. The effluent from the east basin, in turn, flows into the surface ditch. Raw sewage did not enter the east basin except by by-passing, which occurred during stoppages in the line to the new basin. Raw sewage was diverted into the existing west basin at all times to permit suitable variations in flow to be made, and thus to obtain information on the effect of different quantities of raw sewage and limited detention times on both effluent quality and basin operation.

Sewage Characteristics

The raw sewage, supplied by a population of 4,000, is essentially domestic in character. A normal flow of about 0.2 m.g.d. is received at the treatment works. There is no screening of the influent into the basins. Raw sewage temperatures ranged from 60° to 82° F. Settleable solids ranged from 4 to 17 and averaged 9 ml. per liter. Suspended solids ranged from 127 to 550 p.p.m. and averaged 240 p.p.m. The B.O.D. ranged from 110 to 250 p.p.m. and averaged 178 p.p.m.

Percolation and Evaporation

Percolation measurements at the lagoon site were made initially, and then

again after approximately six months of operation. The initial infiltration rate was 8.8 in. per day under a static head of 2 ft. Six months later, the outlet of the new basin was stopped with a static head of 9.0 ft. Percolation at this time had been reduced to less than 0.5 in. per day.

Evaporation in this area amounts to 116 in. per year. The sum of seepage and evaporation losses for the new basin equals approximately 20 ft. per year. With conventional design criteria, such as 1 acre per 100 population, all of the flow from a lagoon in the Mojave area would be lost and no flow would be available for irrigation.

For the 9-month period covered by this report, air temperatures in the test area ranged from a minimum of 36° to a maximum of 92° F. Precipitation for the period was 2.03 in. The average wind movement was 3.4 m.p.h.

Lagoon Operation

The primary lagoon operation was very simple. Sewage was merely introduced into the lagoon through V-notch measuring weirs at manhole openings in the inlet lines. Periodic checks were made to see that the basin inlet lines were not clogged. The installation of the V-notch weirs complicated the maintenance of the basins because of the restricted overflow area provided by the weirs.

The sewers in the Mojave area had been cleaned and tree roots cut. These roots intermittently fouled the V-notch weirs and plugged the inlet into the new basin several times. When the new basin was installed, outlets were supplied in the inlet line to act as diffusers. Because of the impracticality of employing a bar screen to keep out the large material that would clog the small diffuser ports, it was found necessary to pull off the end of the 6-in. outfall line to allow it to discharge full flow. However, this modification did not interfere with diffusion sufficiently to present any major difficulty.

The new basin was designed with a depth of about 9 ft. in order to investigate the feasibility of using relatively deep basins to reduce evaporation losses and to provide good mixing. Satisfactory operation of the basin without the use of the original diffuser would indicate that the depth has assisted in good mixing of the inlet flow with the contents of the basin. Fluorescein dye was introduced into the inlet of the new basin several times. At 1 PM on a calm day in March, 1956, the dissolved oxygen content in the new basin was 8 p.p.m. About 35 g.p.m. of raw sewage was introduced at a temperature of 66° F. The surface temperature was approximately 69° F., and the bottom outlet was 54° F., indicating good stratification. The fluorescein dye, when introduced into the basin, just barely rose to the surface, then sank and disappeared within 5 min. The air temperature at the time of this test was 78° F. The low wind velocities during the observation period allowed stratification and also kept the inlet flows submerged.

A second example of the flow patterns occurred during windy conditions in April. At 10 AM there was no dissolved oxygen present in the new basin. The inflow of approximately 40 g.p.m. was introduced at a temperature of 65° F. The basin temperature from top to bottom was 54° F. Wind velocity was 25 m.p.h. The fluorescein dye, when introduced into the basin, rose to the surface. The dye patch then slowly moved toward the corner of the basin near the inlet and disappeared within 30 min.

These two cases were typical. In general, winds of 10 to 20 m.p.h. caused the basin to mix rather completely. Winds of 5 to 10 m.p.h. caused a breakup of the slight surface scum and could cause all of the scum to be concentrated on one side of the new basin. High-velocity winds caused excessive wave action, which eroded dike embankments.

The discharge from the new basin was

the influent into the east, or secondary, basin. The outlet of the new basin was at the bottom, and the inlet to the east basin was at the surface. The east basin, unfortunately, also received certain overflows of raw sewage as a result of limitations in the test installation, such as clogging of the inlet line to the new basin. Such an occurrence was infrequent, and did not take place at all from December through March. The east basin ordinarily served to provide additional treatment for the effluent received from the new basin; in general, it operated successfully with B.O.D. loadings as great as 800 lb. per day per acre.

The basins were subjected to various rates of flow to determine the effect of different detention times and organic loadings. Six basic loading conditions ranging from 66 to 590 lb. of B.O.D. per acre per day were used in the new basin operation. Data for these B.O.D. loadings and their effectiveness are presented in Table I. The period covered for each of these tests ranged from 2 to 7 weeks. Maximum B.O.D. loading was 590 lb. per acre per day in the new basin. In the east basin, even higher loadings have been applied.

The efficiency of total B.O.D. removal through the new basin has ranged from 59 to 65 per cent. Removals of total B.O.D. after the flow has passed through the secondary lagoon or east basin have ranged from 58 to 76 per cent. In some cases, the total B.O.D. in the effluent from the east basin was greater than in the influent. It is important to realize that the total B.O.D. in the effluent from a lagoon can reflect the algae concentration growing in that basin.

Algae and Plankton

It has been reported that *Chlamydomonas* (the predominant algae) results in a marked increase in oxidizable matter. The soluble B.O.D., therefore, was determined for all effluent samples from the basins. The reduction in B.O.D. in the new basin, based on soluble B.O.D. in the effluent, has ranged from 77 to 92 per cent. The east basin, acting as a secondary lagoon and providing 1 to 6 days of additional detention time, has served to increase the

TABLE I.—Summary of B.O.D. Loading and Removals

Basin	Period (1955–1956)	Average Flow (m.g.d.)	Detention Time (days)	B.O.D. Loading (lb./acre/day)	Average B.O.D. (p.p.m.)			B.O.D. Removal[1] (%)	
					In, Total	Out			
						Total	Soluble	Total	Soluble
New	Nov. 28–Jan. 16	0.184	7	590	218	80	50	63	77
	Jan. 16–Feb. 20	0.044	30	109	170	69	26	59	85
	Feb. 20–Mar. 13	0.030	43	66	150	57	18	62	88
	Mar. 13–Mar. 27	0.043	30	89	132	51	10	61	92
	Mar. 27–Apr. 24	0.144	9	280	134	52	23	61	83
	Apr. 24–May 15	0.077	17	223	199	70	24	65	88
East (as secondary)	Dec. 5–Jan. 16	0.184	1.1	820	80	91	48	58	78
	Jan. 16–Feb. 20	0.044	4.5	169	69	47	21	72	88
	Feb. 20–Mar. 13	0.030	6.7	95	57	36	8	76	94
	Mar. 13–Mar. 27	0.043	4.5	121	51	46	6	65	96
	Mar. 27–Apr. 24	0.154	1.3	489	52–(134)[2]	49	16	63	—[3]
	Apr. 24–May 15	0.087	2.3	410	70–(199)[2]	54	19	73	—[3]

[1] B.O.D. removals for east basin based on total B.O.D. entering new basin.
[2] Strength of by-passed sewage.
[3] 0.01 m.g.d. raw sewage by-passed to this basin.

TABLE II.—Summary of Solids Removals

Basin	Period (1955-1956)	Average Flow (m.g.d.)	Detention Time (days)	Settleable Solids (ml./L)[1]		Suspended Solids		
				In	Out	In (p.p.m.)	Out (p.p.m.)	Removal (%)
New	Nov. 28–Jan. 16	0.184	7	7	Tr.	192	55	71
	Jan. 16–Feb. 20	0.044	30	8	Tr.	270	41	85
	Feb. 20–Mar. 13	0.030	43	8	Tr.	390	90	77
	Mar. 13–Mar. 27	0.043	30	8	Tr.	233	64	73
	Mar. 27–Apr. 24	0.144	9	12	Tr.	209	73	65
	Apr. 24–May 15	0.077	17	10	Tr.	278	82	70
East (as secondary)	Dec. 5–Jan. 16	0.184	1.1	Tr.	Tr.	55	39	29
	Jan. 16–Feb. 20	0.044	4.5	Tr.	Tr.	41	46	0
	Feb. 20–Mar. 13	0.030	6.7	Tr.	Tr.	90	64	29
	Mar. 13–Mar. 27	0.043	4.5	Tr.	Tr.	64	33	48
	Mar. 27–Apr. 24	0.154[2]	1.3	Tr.	Tr.	73	62	15
	Apr. 24–May 15	0.087[2]	2.3	Tr.	Tr.	82	80	2

[1] At 1 hr.
[2] 0.01 m.g.d. raw sewage by-passed to this basin.

over-all soluble B.O.D. removals by 1 to 6 per cent, with the soluble B.O.D. averaging less than 10 p.p.m. for one 5-week period. It is also to be noted that extremely high loadings (820 lb. of B.O.D. per acre per day) in the secondary lagoon, which received the new basin effluent containing *Chlamydomonas*, did not disturb the aerobic activity of the secondary lagoon. The results of the organic loadings applied to the basins show that B.O.D. removals are related to loadings and detention time, as well as seasonal factors.

Table II shows that settleable solids in the new and east basins were very low. It also shows that the reduction of suspended solids in the new basin varied from 65 to 85 per cent, and shows some correlation with flows and detention times.

The raw sewage contains floatable material that sometimes tends to rise to the surface and collect on the downwind side of the new basin, adjacent to the banks. There was no permanent build-up of this floatable material in the aerobic new basin. It was impracticable to try to skim off the floatables because of the continuous introduction of such material into the basin. Each day, with a strengthening of the prevailing wind, the floatables would break down and the surface appearance would be improved. At no time was the new basin ever covered with a floating mat, as was the anaerobic west basin. The biological activity in the new basin resulted in a continuous oxidation and destruction of all the floatable material, as well as other suspended and soluble matter introduced into the basin. Except for very minor occurrences during the winter, no sludge caused by the rising of gas-supported bottom sludge was observed.

The average pH value in the new and east basins was 7.8, a value associated with good algal growth. Results of plankton studies of these basins are summarized in Table III. The quantity of flow during the test period, the detention time, and B.O.D. loading are contrasted with predominant algae growth, which has been measured in standard areal units per milliliter. The operation of the new basin has confirmed the practicality of using a deep basin in order to achieve maintenance of an aerobic environment. Within 10 days after introduction of raw sewage into the new basin, a green algal growth

TABLE III.—Plankton Summary

Basin	Period (1955–1956)	Detention Time (days)	B.O.D Loading (lb./acre/day)	Standard Areal Units (per ml.)		Algae Identified
				Range	Average	
New	Nov. 28–Jan. 16	7	590	$30\text{-}39 \times 10^3$	34×10^3	*Chlamydomonas*
	Jan. 16–Feb. 20	30	109	$31\text{-}58 \times 10^3$	41×10^3	*Chlamydomonas*
	Feb. 20–Mar. 13	43	66	$15\text{-}60 \times 10^3$	37×10^3	*Chlamydomonas, Euglena*
	Mar. 13–Mar. 27	30	89	$59\text{-}86 \times 10^3$	72×10^3	*Chlamydomonas, Euglena, Chlorella*
	Mar. 27–Apr. 24	9	280	$10\text{-}22 \times 10^4$	17×10^4	*Chlamydomonas, Euglena, Chlorella*
	Apr. 24–May 15	17	223	$10\text{-}21 \times 10^4$	15×10^4	*Chlamydomonas, Euglena, Chlorella*
East (as secondary)	Dec. 5–Jan. 16	1.1	820	$30\text{-}57 \times 10^3$	44×10^3	*Chlamydomonas*
	Jan. 16–Feb. 20	4.5	169	$34\text{-}91 \times 10^3$	55×10^3	*Chlamydomonas*
	Feb. 20–Mar. 13	6.7	95	$55\text{-}125 \times 10^3$	97×10^3	*Chlamydomonas, Euglena*
	Mar. 13–Mar. 27	4.5	121	$11\text{-}12 \times 10^4$	115×10^3	*Chlamydomonas, Euglena, Chlorella*
	Mar. 27–Apr. 24	1.3*	—*	$12\text{-}15 \times 10^4$	14×10^4	*Chlamydomonas, Euglena, Chlorella*
	Apr. 24–May 15	2.3*	—*	$12\text{-}20 \times 10^4$	15×10^4	*Chlamydomonas, Euglena, Chlorella*

* 0.01 m.g.d. raw sewage by-passed to this basin.

was established. Counts of *Chlamydomonas* reached 26,000 S.A.U. with a basin depth of 2.5 ft., and ranged from 9,000 to 210,000 during the entire test period.

The plankton in the basins were counted routinely. Counts of plankton in the new basin do not appear to correlate with the B.O.D. loading or detention time. Minimum counts were reached during the winter at low basin loadings and long detention times. Therefore, it is evident that climatic conditions are of great importance in primary lagoon operations.

Some of the lower algal counts were obtained during periods of basin stratification and are a result of the position of the outlet pipe. The effect of depth on algal counts is shown in Table IV. During periods of good mixing, with winds greater than 10 m.p.h., sur-

TABLE IV.—Summary of Algae Counts

Date (1955)	Sample Location	Organisms (no./ml.)			Remarks
		Chlamydomonas	*Chlorella*	*Euglena*	
Mar. 13	New basin, surface	380,000	20,000	5,000	Basin well mixed
	New basin, bottom	240,000	10,000	0	—
	East basin, surface	650,000	60,000	20,000	—
	East basin, outlet	350,000	10,000	10,000	—
Mar. 20	New basin, surface	260,000	6,000	500	Basin stratified
	New basin, bottom	12,000	4,000	500	—
	East basin, surface	3,000	3,000	60,000	3,000 *Chlorogonium elongatum*
	East basin, outlet	1,340,000	160,000	1,000	—
Apr. 3	New basin, surface	320,000	60,000	3,000	Basin well mixed
	New basin, bottom	170,000	30,000	1,000	—
	East basin, surface	330,000	50,000	5,000	—
	East basin, outlet	360,000	60,000	3,000	—
Apr. 24	New basin, surface	690,000	20,000	1,000	Basin well mixed
	New basin, outlet	420,000	20,000	1,000	—
	East basin, outlet	550,000	20,000	1,000	—

face algal counts are usually 1.5 to 2 times as large as the bottom counts. During one period of basin stratification, the surface count was more than 15 times the bottom count.

It also should be noted that *Chlorella* is reported in all samples as the second most numerous organism. The *Chlamydomonas* organism appears to thrive within the relatively deep new basin and appears to be effective in its biological activity and stabilization of organic matter throughout the depth of water. Some water biologists describe *Chlamydomonas* as a protozoa. Actually, it is an organism that appears to have the characteristics of both the animal and plant kingdom, hence may not be completely dependent upon the presence of sunlight, as are true plants such as *Chlorella*.

If this is the case, then the effectiveness of deep basins and the presence of *Chlamydomonas* at the Mojave test are obvious. *Chlamydomonas* and *Chlorella* appeared in greater quantities in the secondary east basin, and this basin usually had higher dissolved oxygen contents. No dissolved oxygen was ever found in the raw sewage and during winter months no more than a trace was ever detected in any except the east basin. In fall and spring, the dissolved oxygen varied from 0 to 12.4 p.p.m. in the new basin and was recorded as high as 27 p.p.m. in the east basin. At times of low dissolved oxygen concentrations in the basins, higher dissolved oxygen contents could be found in the ditch carrying the mixed flow from the east basin.

Bacteriological Results

The results of the bacteriological studies are summarized in Table V. Plate counts and coliform determinations were made in the two basins. It was thought that the bacteriological population could be measured with plate count. Results of these counts clearly show that a reduction in the total number of organisms was always obtained between the inlet and outlet of the primary lagoon. Also shown is the fact that in a secondary lagoon there was usually little change in the total number of organisms between inlet and outlet, but a build-up of organisms appears to have taken place.

The coliform count can be utilized to indicate the extent of purification and

TABLE V.—Bacteriological Summary

Basin	Period (1955–1956)	Detention Time (days)	B.O.D. Loading (lb./acre/day)	Plate Count (×10⁴)		Average M.P.N. (per ml.)[1]		
				Inlet	Outlet	Inlet	Outlet	Removal (%)
New	Nov. 28–Jan. 16	7	590	190	53	61,000	30,000	51
	Jan. 16–Feb. 20	30	109	200	18	72,000	15,000	79
	Feb. 20–Mar. 13	43	66	97	24	35,000	8,300	76
	Mar. 13–Mar. 27	39	89	160	28	67,000	13,000	81
	Mar. 27–Apr. 24	9	280	230	79	45,000	32,000	29
	Apr. 24–May 15	17	223	210	59	150,000	13,000	91
East (as secondary)	Dec. 5–Jan. 16	1.1	820	53	44	30,000	12,000	80
	Jan. 16–Feb. 20	4.5	169	18	17	15,000	8,800	88
	Feb. 20–Mar. 13	6.7	95	24	31	8,300	4,200	88
	Mar. 13–Mar. 27	4.5	121	28	58	13,000	5,400	92
	Mar. 27–Apr. 24	1.3[2]	—[3]	79	78	—[3]	15,000	67
	Apr. 24–May 15	2.3[2]	—[3]	59	102	—[3]	30,000	80

[1] Coliform removals for east basin based on total coliform entering new basin.
[2] 0.01 m.g.d. raw sewage by-passed to this basin.

stabilization occurring in the basins. The average coliform removal in the new basin ranged from 29 to 91 per cent. The average coliform removal in the east basin ranged from 67 to 92 per cent, with the low removals occurring when raw sewage was by-passed into the east basin. It should be remembered that the possibilities of cross connection and poor mixing, as well as the noted by-passing of raw sewage, interfered with obtaining better coliform removals.

Odors and Mosquitoes

The range of odors encountered at the lagoons was similar in magnitude to those encountered at most conventional treatment plants. Studies of the slight odors normally associated with the primary aerobic lagoon operation indicate that the main source of these odors was probably the fresh, floatable matter present in the lagoons. Slight odors connected with the life processes of the new basin seemed to be in the effluent and would sometimes be noticed in the vicinity of the basin when wind caused mixing of the deeper waters.

No significant odors were present in the effluent from the secondary lagoon. No sulfides were ever found in the new or east basin samples for the period covered by this report, but were always present in the raw sewage and in the anaerobic west basin samples. The presence of slight odors in the new basin is believed to be a factor that should be considered carefully by anyone interested in utilizing lagooning as a sewage treatment process. The new basin was not completely odor free. However, it should again be emphasized that minimum odors will be encountered when the intallation is properly designed, constructed, and operated.

No mosquitoes were encountered throughout the test period. The prevailing winds in the Mojave area, resulting in the previously reported mixing within the basin, probably provide natural mosquito control. In addition, the growth of vegetation was controlled by steep slopes and routine maintenance.

Effluent Use

The importance of water to a desert community or desert area is obvious. Water, in addition to being limited in quantity, is of considerable monetary value. The sewage effluent at the Mojave test site was of suitable mineral quality for irrigational use. The 700 p.p.m. of dissolved solids, the 60 per cent sodium ratio, and the low chlorides and sulfates, placed this effluent in Class II of standards of quality for irrigation waters.

The sodium percentages ranged from 50 to 64. The boron content was within the tolerant range, being less than 0.8 p.p.m. The phosphate content of the effluent from the east basin was 28 p.p.m., and the total nitrogen content ranged from 26 to 36 p.p.m. Potassium was measured at 10 to 13 p.p.m. Toxic elements, such as arsenic and copper, were found in only one set of samples of raw sewage and lagoon effluents, and were probably attributable to sewer cleaning activities. Reclamation of this effluent should assist in conserving the existing native waters for higher use as a potable water.

Conclusions

Sampling of the lagoons during the hot desert summer has produced much additional, interesting data. Valuable operating experience also has been secured. However, because there has not been adequate time to interpret and evaluate these data and formally submit the additional findings to the California State Water Pollution Control Board, sponsor of the research, the results of the 1956 work could not be included in this paper. Until there has

been time to develop further complete engineering criteria for primary lagoon treatment, the design of such units should proceed with caution.

It would appear that basins designed similar to the new basin and used in similar locations should provide average B.O.D. removals of 60 per cent and soluble B.O.D. removals of 85 per cent under continuous loadings upwards of 100 lb. of B.O.D. per acre per day. It is further concluded that the selected depth of approximately 9 ft. made possible desirable influent mixing and diffusion, and that a detention time of less than one month, resulting in percolation and evaporation losses less than 20 per cent of the sewage flow, makes this system particularly suitable for waste water reclamation.

SECOND NUCLEAR ENGINEERING AND SCIENCE CONFERENCE

The Federation is one of 20 sponsoring organizations of the Second Nuclear Engineering and Science Conference to be held in Convention Hall, Philadelphia, Pa., March 11–15, 1957. The Conference is the main technical feature of the 1957 Nuclear Congress, which includes the 5th Hot Laboratories and Equipment Conference, the 5th Atomic Energy in Industry Conference, and the 3rd International Atomic Exposition. The Engineers Joint Council is coordinating the Congress activities.

Included in the 32 sessions of the Conference are two devoted to wastes disposal. The program for these sessions is as follows:

Monday Afternoon, March 11

Chairman: John C. Geyer; Vice-Chairman: Joseph A. Lieberman

"Disposal of Radioactive Wastes," by Abel Wolman.

"Over-All Geological Approach to Disposal," by H. H. Hess.

"Underground Movement of Radioactive Wastes," by Warren J. Kaufman and Gerhard Klein.*

"Problems Facing State Enforcement Agencies in Handling Treatment and Disposal of Radioactive Wastes," by Emil C. Jensen, E. F. Eldridge, C. M. Everts, Jr., and H. C. Clare.*

Tuesday Morning, March 12

Chairman: Roy J. Morton; Vice-Chairman: Blucher A. Poole

"Disposal of Fission Products in Glass," by R. W. Durham.

"Factors Controlling Temperature Rises Within Radioactive Wastes Buried in the Earth at Depths," by Herbert E. Skibitzke.

"Atomic Wastes Disposal by Injection into Aquifers," by Edwin Roedder.

"Separation of Cesium and Strontium from Calcined Metal Oxides as a Process in Disposal of High-Level Wastes," by A. Abriss, J. J. Reilly, and E. J. Tuthill.

* Papers sponsored by FSIWA.

ENLARGED SEWAGE DISPOSAL FACILITIES FOR LOS ANGELES *

By Robert J. Theroux

Project Engineer, Hyperion Engineers, Los Angeles, Calif.

In the spring of 1955 the city of Los Angeles voted a $60,000,000 bond issue to provide additional facilities for collection and disposal of the city's sewage. This action was in response to the recommendations of a Citizens' Committee and its engineering consultants. Of this sum, $19,300,000 is to be used for local sewers to be designed by the Los Angeles City Bureau of Engineering. The other $40,700,000 is to be used for construction of a new outfall sewer and final disposal facilities.

This latter work is being designed by Hyperion Engineers, which is a joint venture among the three Los Angeles engineering firms of Holmes & Narver, Inc.; Daniel, Mann, Johnson & Mendenhall; and Koebig & Koebig. Hyperion Engineers' contract with the City of Los Angeles is for the design of the following items in accordance with the Citizens' Committee report: $14,000,000 for the North Central outfall sewer, $3,000,000 for an ocean outfall for digested sludge, $16,000,000 for an ocean outfall for effluent, and $7,700,000 for additional facilities at the Hyperion treatment plant.

When the Citizens' Committee program is completed, the average flow capacity of the Los Angeles sewers and disposal facilities will be increased from 245 m.g.d. to 420 m.g.d. The average flow today is about 255 m.g.d.

North Outfall Relief

The new North Central outfall, shown in Figure 1, conveys sewage from La Cienega Blvd. at Rodeo Road to the site of the existing Hyperion treatment plant. This sewer, now under construction, is 9.5 ft. in diameter and 42,000 ft. long. Approximately two-thirds of the sewer is in tunnel. After extensive investigation it was decided to protect the sewer with vinyl plastic liner against corrosion due to the generation and subsequent oxidation of hydrogen sulfide.

The outfall has two inverted siphons, one of which is approximately 2,600 ft. long. The sewer is ventilated throughout its length by means of ventilation fans located at the Hyperion treatment plant. At the inverted siphons the ventilation air is carried by jumper pipes from one end of the siphons to the other. This North Central outfall sewer relieves the existing overloaded North outfall sewer. The North Central outfall was located in such a manner as to miss the most severe part of the fault zone in the Baldwin Hills.

Hyperion Plant Enlargement

The existing Hyperion treatment plant is a high-rate activated sludge plant with an average flow capacity of 245 m.g.d. The effluent is discharged through a mile-long ocean outfall into some 50 ft. of water. The sludge produced at the treatment plant is digested, vacuum filtered, and dried to be sold for fertilizer. The existing plant was placed in full operation in 1951.

The Citizens' Committee program is directed toward enlarging the Hyperion plant capacity to 420 m.g.d., and toward reducing the operation cost as

* Presented at 1956 Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Los Angeles, Calif.; Oct. 8–11, 1956.

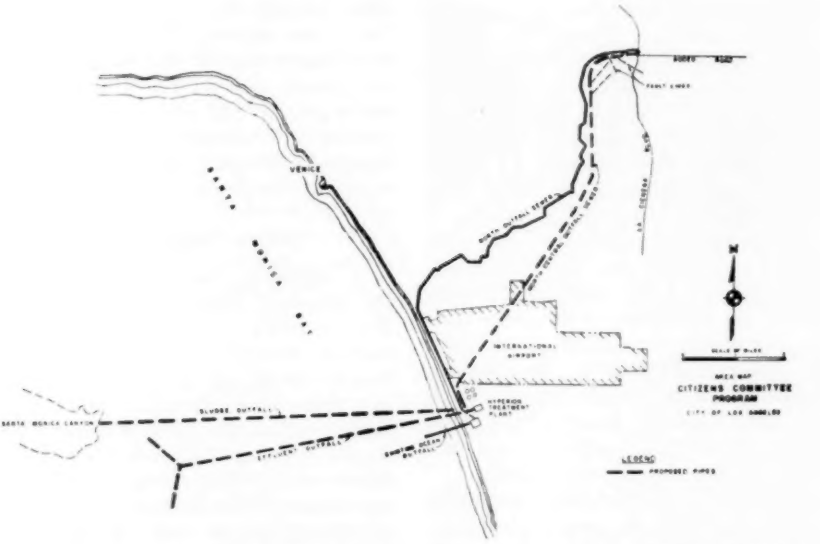

FIGURE 1.—Proposed North Central sewer, and new sludge and effluent outfalls.

much as possible. The basic plan is to modify the treatment provided at Hyperion in such a fashion that an average flow of 300 m.g.d. of sewage will receive primary sedimentation only before being discharged to sea. Another 120 m.g.d. will receive conventional activated sludge treatment in the existing aeration and final settling tanks and will then be either discharged to sea or reclaimed as industrial or ground recharging water.

The combined effluent will be pumped through a 5-mile long, 12-ft. diameter

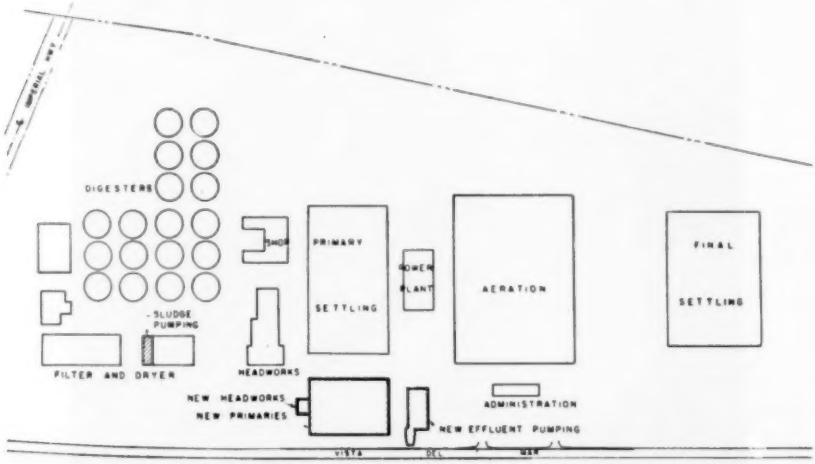

FIGURE 2.—Major additions needed at Hyperion plant to increase capacity to 420 m.g.d. under modified treatment.

ocean outfall extending to a water depth of 194 ft. Sludge produced by the treatment process will be digested and then pumped through a 7-mile long ocean outfall, to be discharged at a depth of 300 ft. The existing vacuum filters and sludge dryers will be "mothballed" until such time as the production of fertilizer becomes profitable.

A comprehensive program of oceanographic investigation has been undertaken by the Allan Hancock Foundation of the University of Southern California, under the general supervision of Hyperion Engineers. This investigation is to determine factors which will bear upon the design of the ocean outfall for sewage effluent and the ocean outfall for digested sludge.

The major items of work necessary at the Hyperion treatment plant site, under the Citizens' Committee program, are shown in Figure 2. They consist of a pumping station to discharge the digested sludge to sea, a new headworks building to house screening equipment, a new grit removal facility, and a bank of new primary settling tanks; all of which increase the capacity of the plant from an average flow of 245 m.g.d. to the anticipated flow in the year 2000 of 420 m.g.d. It will also be necessary to construct an effluent pumping station, capable of pumping 600 m.g.d. through the 5-mile long ocean outfall.

Water Reclamation

In addition, various modifications are necessary around the plant to enlarge existing facilities or to correct existing deficiencies. One interesting facility which has been designed is a flow interchange structure which provides some choice as to whether flow from the North Central outfall or the North outfall goes to the existing or new parts of the treatment plant. The purpose of this is water reclamation. It has been found that the bulk of the chlorides in the Los Angeles sewage are derived from the coastal areas near Venice and Santa Monica. This saline sewage is the least desirable for water reclamation purposes. It is therefore advisable to restrict the saline flow so

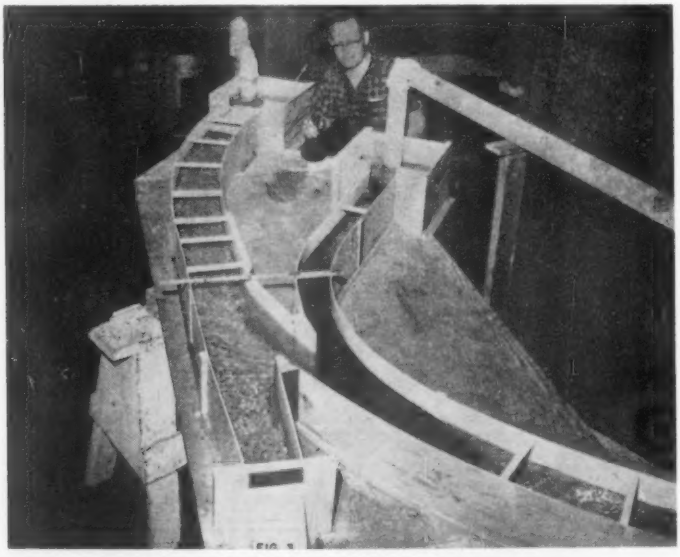

FIGURE 3.—Model of flow interchange structure.

that it does not enter the activated sludge units, where sewage will be purified to an extent that it is useful for reclamation purposes.

A model of the interchange structure, shown in Figure 3, was constructed on a 1-to-20 scale and operated by the California Institute of Technology. The model demonstrated the hydraulic characteristics of the interchange structure and showed conclusively that it would accomplish its purpose of separating the saline and non-saline waters.

Grit Removal

An existing deficiency in the present plant which is being corrected by the new design is grit removal. Some grit passes the existing detritors and accumulates in the preaeration tanks, where there is no feasible means of removing it. To correct this difficulty a tubular conveyor will be installed beneath the swing diffusers in the existing preaeration tanks.

The conveyor (Figure 4) consists of a pipe through which a specially constructed link chain is passed. A disc, which fits loosely within the pipe, is attached to each link of the chain. This endless chain is driven by a sprocket and motor, and the upper half of the pipe is cut away in the grit pickup section, as shown in Figure 5. There are no sprockets or bearings in the sewage. This device is being installed in the first pass of each of the two preaeration tanks, each pass being 300 ft. long.

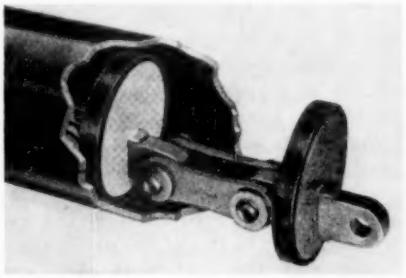

FIGURE 4.—Articulated flights of tubular conveyor allow non-planar curves.

The grit is conveyed from the pickup conveyor to a transfer conveyor, thence to a conveyor which elevates it to a grit storage hopper for truck removal.

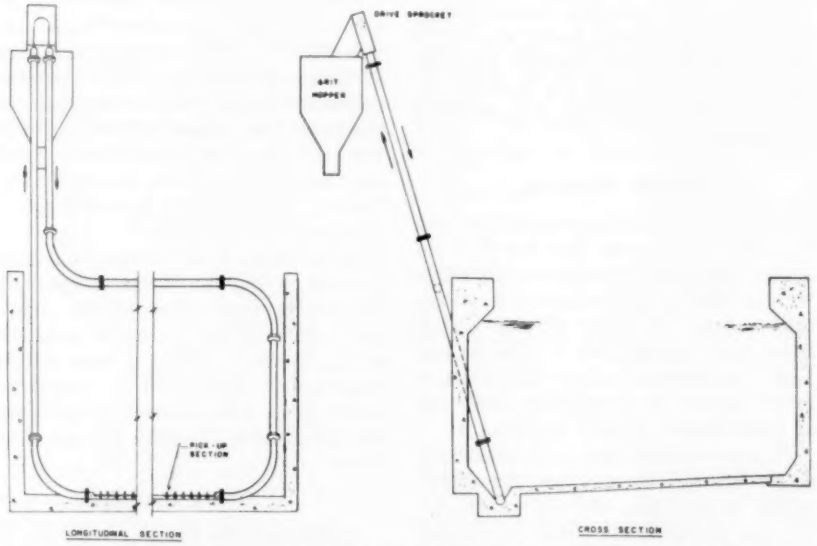

FIGURE 5.—Hapman conveyor for elevation of grit from aerated grit tanks.

This device was selected after studying all other feasible means of grit removal and considering the adverse conditions at Hyperion. One of these is caused by having the swing diffusers hung in the aeration tanks in such a position that they could interfere with many types of grit removal mechanisms. Another problem is the extreme depth (15 ft.) of the preaeration tanks, and the fact that they are covered with a concrete slab, with the only openings being removable aluminum cover plates. Since there are only two grit removal tanks, if one unit is out of service one-half of the entire preaeration and grit removal facility is thus out of action.

As far as is known, the only previous applications of this type of conveyor for grit removal have been at the new Village Creek sewage treatment plant near Birmingham, Ala., and at a small plant in Auburn, N. Y. Both of these plants use the conveyor in such a fashion that the pickup section is comparatively short, whereas in the case of Hyperion the length of the existing tanks dictates a comparatively enormous collection device. However, the tubular conveyor is in common industrial use for handling abrasive materials and it appears to be a good gamble as being an improvement over the known deficiencies of conventional grit removal equipment.

Sludge Pumping

The digested sludge pumping station has been so arranged that the digested sludge containing 3 to 4 per cent solids will be diluted with about two times that volume of plant effluent water, prior to being pumped 7 miles to sea. This was designed after an extensive investigation of all existing examples of long-distance sludge pumping.

It appears that the most important single factor is to maintain the sludge solids in a state whereby their hydraulic characteristics will be similar to that of water. The sludge pumping station is so arranged that the sludge can be pumped out continuously with an amount of plant effluent to make a constant flow, or the sludge can be stored in one of three existing elutriation tanks and the sludge pumped out intermittently. The preponderance of evidence indicates that it will be better to keep the flow continuous and relatively constant in the sludge outfall, whether that flow be sludge plus some dilution water or whether it be all dilution water.

It is anticipated that the daily quantity of sludge to be pumped to sea will be approximately 2.5 million gallons by the year 2000. In the design of the sludge pumping facilities an allowance was made for increase of sludge due to increased use of garbage grinders. Provision was made for the insertion of a cleaning "pig" in the sludge outfall.

Gas Facilities

It was necessary to construct additional facilities for the removal of gas from the digesters. However, negotiations are under way at the present time aimed at selling the excess Hyperion digester gas to the Los Angeles Department of Water and Power, which has a steam turbine plant under construction at the south boundary of the Hyperion treatment plant. This electric generating plant uses either natural gas or oil for fuel. It is anticipated that a substantial revenue will be available to the Bureau of Sanitation from the sale of this gas.

In addition it saves the embarrassment of having the enormous waste gas burners in plain view of the public, while there is on the south boundary of the treatment plant a huge electric generating plant which purchases many times that amount of gas from fuel companies bringing the gas from Texas.

Primary Settling

Approximately two-thirds of the total flow of sewage will pass through the

existing primary settling tanks. The other one-third of the raw sewage will pass through a new Venturi meter, bar screens, grit removal, and primary settling tanks before being discharged to sea or receiving secondary treatment. These facilities are shown in Figure 6.

The new grit removal facilities will be of the aerated tank type. Again, tubular conveyors will be used to pick up the grit and transfer it to elevated storage hoppers for truck disposal. The new primary settling tanks were determined to be necessary by settling experiments performed at the Hyperion plant. These experiments showed that the overflow rate for which the existing primary tanks were designed (1,800 g.p.d. per square foot) could not be much exceeded and still get any benefit at all from the tanks. If new tanks are not constructed the overflow rate would be some 3,100 g.p.d. per square foot.

It was not certain whether or not this rate was out of reason until the experiments showed that the removal of settleable solids would be markedly less than Hyperion's usual reduction of from 12 ml. per liter in the raw sewage to less than 1 ml. per liter in the primary effluent at a flow of 2,000 g.p.d. per square foot. Instead, the settleable solids were on the order of 3 or 4 ml. per liter in the effluent from the tank performing at a rate of 3,100 g.p.d. per square foot.

The new primary settling tank battery will be of a size equal to one-half of the existing primary settling capacity. This results in an overflow rate, by the year 2000, of 2,100 g.p.d. per square foot. The new primary tanks will have a slab over them, as has been the policy at Hyperion, except that a building will enclose the effluent end of the tank where the scum removal equipment and weirs are located. This building will be 74 ft. wide and 236 ft. long.

The length of weirs will be 50 ft. and the total length will be such that the average weir overflow rate will be about 60,000 g.p.d. per lineal foot. The existing primary tanks have a weir loading rate of 40,000 g.p.d. per lineal foot. This high weir loading rate was decided on after experiments at Hyperion showed that equally good results were obtained with a loading rate of 70,000 as with 40,000 g.p.d. per lineal foot.

The weirs will be of the straight-edged type, rather than notched, because with an average loading of 60,000 g.p.d. per lineal foot the average depth over the weirs will be approximately 1 in. Scum will be removed from the new primary tanks by means of flights up to the scum barrier, and then by water sprays in the weir area itself. The weirs are all longitudinal in alignment so that any scum which

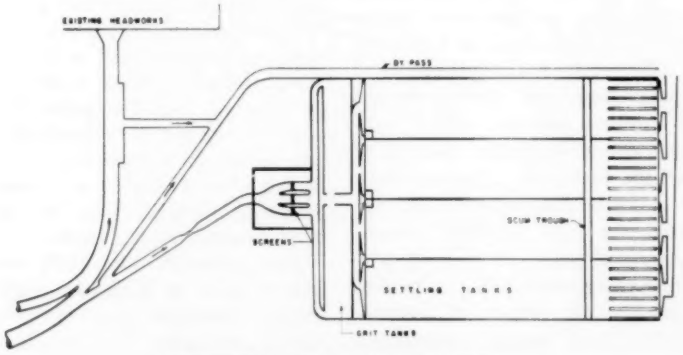

FIGURE 6.—New primary facilities.

escapes the scum barrier can be driven back by means of the water sprays to the scum trough, where it is picked up by a rotary-type skimmer.

A scum baffle will project some 6 in. from the weirs themselves to prevent the scum from falling over the weirs. This represents some improvement over the arrangement in the existing primary tanks, wherein any scum which gets past the scum barrier has to be discharged to the next treatment plant unit or to sea.

The depth of water in the effluent launders will be maintained at a comparatively constant level. This will be accomplished by means of a discharge level control valve, which will automatically maintain the desired depth. The purpose is to reduce the spill of water over the weir, with consequent release of hydrogen sulfide. This has been a substantial problem in the existing primary tanks, where extensive corrosion of the concrete in the weir area has occurred.

Preaeration

No formal preaeration is being provided for the new primary settling tanks. Investigations regarding preaeration were performed at the existing Hyperion plant, which incorporates 25 min. of preaeration prior to 1.5 hr. of sedimentation.

The only significant improvement of the sewage due to preaeration which could be detected by laboratory analyses was some reduction in hydrogen sulfide. There was no improvement in either the suspended solids or the settleable solids removal, and a very small improvement in the removal of ether-soluble material. Consequently, it was not felt that preaeration was warranted for Los Angeles sewage. However, a certain amount of preaeration is accomplished in the aerated grit removal tanks, which will provide 8 min. of aeration time at average design flow.

Odor Problem Investigation

A major investigation was made of the odor problem at the Hyperion plant. All of the treatment plant facilities up to and including the primary settling tanks are covered or housed in buildings. The ventilation air from these structures is disposed of either by discharge from the tops of the buildings or by transfer to the stack used for the combustion products from the sludge drying operation. However, there has been some odor nuisance from the plant, which is adjacent to the City of El Segundo and is also very near the existing, and even nearer to the future, Los Angeles International Airport Terminal.

The ventilation system leading to the stack has some imperfections in it, but what air does get to the stack has a debatable fate. Under certain conditions, the stack is an effective means of dispersing and eliminating odor nuisance. However, under other atmospheric conditions the stack is comparatively useless.

An experiment was set up at the Hyperion plant aimed at using the ventilation air as makeup air for the blowers supplying air to the activated sludge tanks. The experiment demonstrated that foul air from ventilation sources could be passed through the mixed liquor in the activated sludge tank and emerge with no more odor than is the case when clean air is introduced into the activated sludge.

Consequently, the entire new primary settling system and the North Central outfall sewer, totaling 112,000 c.f.m. of air, will be ventilated by conducting the air to the makeup plenum where air is introduced into the existing five 40,000-c.f.m. blowers for eventual disposal into the activated sludge mixed liquor tanks.

An operation somewhat similar to this is done on a smaller scale at the sewage treatment plant at Sacramento, Calif., and gases from an incinerator are disposed of by a similar method at

the Richmond Sunset plant at San Francisco. It may seem inconsistent to take ventilation air, some of which has been collected from the preaeration tanks, and to then pass that air into the activated sludge units for scrubbing. However, it is a matter of the relative amounts of hydrogen sulfide and dissolved oxygen in the water involved. In the case of the preaeration tanks, there is plenty of hydrogen sulfide and no dissolved oxygen. In the case of the activated sludge tanks the reverse is true. Consequently, hydrogen sulfide will be dissolved and oxidized in the mixed liquor.

Effluent Pumping Station

A very prominent feature of the modified Hyperion plant will be the effluent pumping station, shown in Figure 7. This will be housed in a building 171 ft. long, 74 ft. wide, and 80 ft. high. The pumping station, required under the Citizens' Committee program, is designed for a dry weather peak flow of 600 m.g.d., with capability of expansion to 720 m.g.d. at a later date if justified.

The pumping will be accomplished by vertical dry pit pumps. Before deciding on this type of pump, considerable investigation was made of other arrangements, including wet pit pumps, which were discarded because of their poor maintenance features and difficult flow entry characteristics; horizontal pumps, which were discarded because of their space requirements and flooding danger; and variable-pitch propeller pumps, which were discarded because of their poor experience record.

There will be five pumps in the pumping station, with space for a sixth. Three pumps will be driven by wound-rotor motors, and two by synchronous motors. It is necessary to have speed control for some of the pumps, since the bulk of the total head of 64 ft. is friction head. In fact, pumping is actually downhill, because the water level in the pump station is higher than sea level. During many hours of the day it will be possible to discharge the entire flow of the plant by gravity. However, each day it will be necessary to pump as the flow increases beyond 300 m.g.d.

Various means of achieving speed control of the pumps were considered, including magnetic drives and torque converters. For the size equipment involved (2,500 h.p. motors) operating at

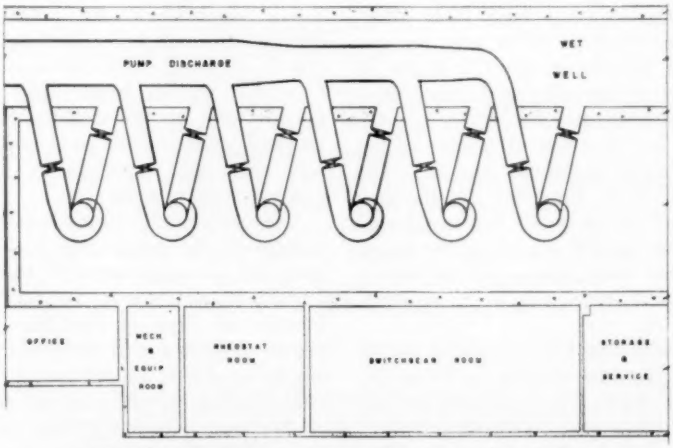

FIGURE 7.—Layout of new effluent pumping station.

315 r.p.m., there was insufficient experience record to justify installation of anything except wound-rotor motors.

The pump station will be entirely automatic, and as the flow increases the pump motors will be started electronically based on data from the Venturi meters at the head of the sewage treatment plant. As the water level in the wet well of the pumping station rises, the pump discharge valves will open and simultaneously the gravity flow valve will close. Practically all valves in the effluent pumping station will be butterfly type. They will be operated by electric motors, except that the gravity flow valve will operate by hydraulic force in order to allow its operation in the event of power failure.

Power for Pumps

Power for driving the pumps will be provided from the power generated at the Hyperion plant by the existing gas engines and also by an external power connection to the Department of Water and Power system. There is insufficient power generated at the Hyperion plant to pump all of the sewage all of the time, and there is also the reliability advantage in having the external power connection.

New and Old Outfalls

The existing 1-mile long, 12-ft. diameter ocean outfall will be used for discharging approximately 120 m.g.d. of activated sludge effluent during times of peak storms, and also will serve as a standby in the event of failure of the new effluent pumping station. The proposed 12-ft. diameter, 5-mile long ocean outfall, plus the existing 1-mile long ocean outfall can carry the entire storm flow which can reach Hyperion, estimated at 720 m.g.d., to sea by gravity.

A facility has been designed in the effluent pumping station to allow the insertion of a cleaning go-devil, or ball, to clean the proposed effluent outfall.

The new 12-ft. effluent outfall will be constructed of reinforced concrete. The inshore portion of the effluent outfall will be buried beneath the ocean floor, in a trench excavated for that purpose. However, the balance of the pipe will be laid on the ocean floor, and will have no protection other than rock around it up to the spring line. Divers can work for only 35 min. on the bottom at the extremity of the outfall, where the depth will be 194 ft., so it is important to keep the amount of underwater work to the minimum.

The main pipe of 12-ft. diameter will terminate 5 miles from shore. From that point there will be two 4,000-ft. legs, which will comprise the diffuser section of the pipe. Holes varying in diameter from 6¾ to 8⅛ in. will be spaced along the spring line of the diffuser sections. Great importance is placed upon proper diffuser design, because this enlarges the amount of dilution obtainable in the vicinity of the outfall discharge.

The ocean pipe was designed under the assumption that the n value in the main part of the pipe would eventually rise to 0.018, and in the diffuser sections to 0.022. When the n value becomes that high it is intended to clean the pipe with a go-devil.

Sludge Discharge

The digested sludge will be discharged through a 7-mile long line in 300 ft. of water. The 22-in. steel pipe is coated on the inside with cement mortar, and on the outside with coal tar and gunite. This pipe is provided with cathodic protection of the impressed current type.

The outfall will be anchored to the bottom of the ocean, and has already been bid at approximately $2,500,000. It will be constructed by joining the lengths of pipe by welding on the beach, and then will be pulled out to sea by anchored barges.

Flexibility is provided in that the sludge outfall into the ocean will not be the sole means of disposal of di-

gested sludge, since the existing elutriation tanks, vacuum filters, and flash dryers will be left intact, ready for operation in the event that the fertilizer market warrants the operation of these facilities.

Effluent a Water Source

The designs of all the facilities have been governed to a considerable extent by the water reclamation factor. Water is in short supply in Southern California and will become more expensive as additional supplies must be brought from greater distances. There is also a serious salt-water intrusion problem in the Los Angeles basin.

At present, water is purchased to inject into wells for the purpose of recharging the ground-water supplies and erecting a fresh-water mound to prevent salt-water intrusion. However, this is expensive and it is hoped that one source of comparatively cheap water will be the standard-rate activated sludge effluent from Hyperion.

The activated sludge portion of the Hyperion plant will be capable of being operated on a more or less flat flow basis to produce as good a quality of water as possible, while the balance of the flow will be discharged through the 5-mile pipe to sea as primary effluent. It is believed that 100 or 120 m.g.d. of highly purified effluent will be available for reclamation purposes, either for recharging into the ground or for use by industries.

Design Provides Flexibility

All of the factors which bear upon ocean disposal of sewage have been investigated to the fullest extent practicable. The facilities have been so designed that considerable flexibility has been provided, enabling the operator to modify the treatment to accommodate changes in the raw sewage characteristics, requirements for water or fertilizer reclamation, and possible changes in ocean disposal standards.

USPHS SANITARY ENGINEERING TRAINING PROGRAMS

Specialized training courses scheduled at the USPHS, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, from February through May, 1957, are as follows:

Feb. 25–Mar. 1.	Detection and Control of Radioactive Pollutants in Water
Mar. 4–15	Advanced Training for Sanitary Engineers in Water Supply and Water Pollution
Mar. 18–29	Basic Radiological Health
Apr. 1–12	Environmental Radiation Sanitation
Apr. 15–19	Industrial Wastes: Chemical and Biological Determinations; Metals, Cyanides, Phenols
Apr. 22–26	Air Pollution Meteorology
Apr. 29–May 3	Evaluation of Air Pollution Effects on Vegetation
May 6–10	Aquatic Biology in Water Pollution
May 13–14	Bioassay of Industrial Wastes
May 13–17	Radiological Health Aspects of Nuclear Reactors
May 20–24	Control Methods for Air Pollution Sources
May 27	Individual Household Sewage Disposal Systems

These courses are available to professional personnel engaged in the particular programs for which courses are listed. Application forms may be obtained from the Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio, or any regional office of the Department of Health, Education and Welfare.

PRELIMINARY REPORT ON RECOMMENDED UNITS OF EXPRESSION FOR DESIGN AND OPERATION OF SEWAGE AND INDUSTRIAL WASTES TREATMENT PLANTS*

Prepared Under the Direction

of the

Committee on Sewage and Industrial Wastes Practice, Federation

of Sewage and Industrial Wastes Associations

By The Subcommittee on Standardization of Units

H. E. Orford, *Chairman*

Dr. Morris M. Cohn, Chairman of the Federation's Committee on Sewage and Industrial Wastes Practice, has announced that the Subcommittee on Standardization of Units, under the Chairmanship of H. E. Orford, has prepared a tentative draft of a "Manual of Units of Expression for the Design and Operation of Treatment Plants." This is the outgrowth of approximately 13 years study and the amassing and evaluation of much information of vital importance to the sewage and industrial wastes field. The group which has worked on this important project has expressed the desire to place its recommendations, in their present tentative form, before the entire membership of the Federation in order to obtain a broad cross-sectional reaction to its proposals. Since these proposals will, if adopted and promulgated as the recommended "standard" units of expression of the profession, have a vital impact on everyone engaged in the designing, equipping, and operating of collection, treatment, and disposal facilities for sewage and industrial wastes, the Committee on Sewage and Industrial Wastes Practice concurred in the view that it would be valuable to have the full Federation membership participate in an open review and discussion of material which will in time become the intended "practice" of the organization and, through it, of the state and sectional associations which form the Federation.

The decision to present to the membership the tentative proposals of a Subcommittee prior to their adoption, represents a departure from the previous procedure followed by the Sewage and Industrial Wastes Practice Committee. It will also be a new experience for the membership to have the opportunity to participate in the discussion of these new standards and it is hoped that full advantage will be taken of the opportunity thus presented.

In order to give the Federation membership a clear insight into the work of the Subcommittee, it will be valuable to review the established pattern of procedure by which a Federation Committee works up a report which may eventually be published as an official document or "Manual" of the Federation. After a long period of study and research the group's conclusions are incorporated in a preliminary draft of a report which is distributed to per-

* Approved for publication as a tentative report in This Journal by the Federation Board of Control on October 7, 1956 at Los Angeles, Calif.

sons, organizations, and manufacturing firms which are directly interested, or have special knowledge and proficiency in the matters covered. All comments and criticisms are evaluated and translated into modifications of the drafts before they become final. The revised draft must then be reviewed and approved by the Committee on Sewage and Industrial Wastes Practice, the Publications and Program Committee, and the Executive Committee. In addition, the Board of Control must authorize the expenditure of funds for publication.

The Subcommittee on Standardization of Units was organized in 1943, under the original chairmanship of Dr. Willem Rudolfs. It is composed of approximately 50 persons prominent in the wastes disposal field. Since 1952 its work has been done under the direction of Dr. Harold E. Orford, its present chairman. The procedures discussed in the previous paragraph have been followed to the point of presentation of a preliminary draft. What remains to be done is to obtain the suggestions of all Federation members who wish to make their views known on this important matter. These will be given most serious consideration by the Subcommittee and incorporated, where feasible, into the draft presented for final review.

Please send your comments to the Federation Headquarters.

Basic Considerations

To fully understand the basis for the suggested units of expression it is important to consider the objectives and specifications which served to guide the Subcommittee in making its deliberations. Presented here are the basic considerations and philosophy of the Subcommittee.

Objectives

1. To select, for the design and operation of waste treatment plants, units of expression recommended for use in reporting results in technical journals and other publications.

2. To reduce the number of equivalent units of expression used.

3. To develop a system of units that can be defined in common terms.

4. To agree upon units that are widely used and understood, as far as it is possible to do so and accomplish the other objectives.

Specifications

From these objectives and from the suggestions of the subcommittee members, it was possible to set up specifications that would simplify the selection of units. The most important specifications for the choice of recommended units are listed below:

1. Only one unit of a particular type should be chosen.

2. The magnitudes usually associated with the use of the selected unit should be small whole numbers, preferably between 1 and 100.

3. The number of different units of length, weight, and time should be reduced to a minimum.

Committee Comment

With these objectives and specifications in mind, units were selected for review by the committee members. Four reports were submitted to the committee. Each time, units were replaced or removed, simplifications were suggested and, slowly, general agreement was reached on the units to be included. It is significant that as the selected units became more and more fundamental, the greater was the agreement of the committee.

It was agreed, first of all that, except in unusual circumstances, the foot-pound-second (time) system should be made the basis of all units. It was agreed further that the units recommended should be, in general, units that have been widely used. Finally

it was agreed that the cubic foot should be substituted for the gallon as the standard unit of volume. As will be seen, this fundamental recommendation simplifies many calculations and many volume-dependent units of expression. No satisfactory fundamental system of units could have been developed without making this change.

The committee members adopted this recommendation only after long and careful deliberation. Adoption was almost unanimous, however, because it was realized that the long-range advantages of the new system far outweigh all short-range difficulties.

The list of recommended units submitted herewith is annotated. For most units, a range of numerical values is indicated for current sewage treatment practice to provide a guide for their evaluation. Also given after each unit is a list of the directly comparable units in current use together with the conversion factor by which the recommended unit is obtained.

One departure from the fundamental foot-pound-second (time) system was necessary. This is the use of milligrams per liter recommended in the 10th Edition of Standard Methods as the expression for concentration.

Recommendations

The following recommendations are made to implement the use of the recommended units and to promote their acceptance by the profession:

1. That the recommended units of expression be used in presenting material published in technical journals, and other publications.
2. That non-recommended units of expression be used only where it is found necessary to do so and there is no recommended unit.
3. That non-recommended units of expression conform wherever possible to the specifications for selecting the recommended expressions.
4. That a permanent committee on Units of Expression be appointed. This committee should be similar to the Standard Methods Committee. It should collaborate with committees from other technical organizations to standardize units of expression and it should meet often enough to keep the list of recommended expressions up to date and to satisfy the needs of the represented professions.

The committee fully understands that the units recommended present radical departures from those used in current practice. An examination of the recommended units will reveal, however, that the only basic change is the substitution of the cubic foot for the gallon as the unit of volume. This change was recommended only after much thought by the subcommittee. Without this substitution, no consistent simplified system of units was possible.

RECOMMENDED UNITS OF EXPRESSION [1]

Wastes

Volume

Sewage: cubic feet per day.

Strength [2]

Sewage and industrial waste: (a) milligrams per liter, (b) pounds per 1,000 cu. ft.

[1] For many of the units recommended, the numerical range of values usually encountered is given under each unit. These numerical values are only background figures. They have no other significance with respect to the recommendations made or the use of the unit.

[2] Concentration of B.O.D., suspended solids, etc.

Efficiency of Treatment [3]

Sewage and industrial wastes: percentage removal of a particular constituent (B.O.D., suspended solids, etc.); (influent − effluent)/(influent) × 100.

Unit Replaced	Conversion Factor [4]	Recommended Unit
Gallons per day	× (1/7.5)	= Cubic feet per day
Gallons per minute	× 192	= Cubic feet per day
Parts per million	× (1/16)	= Pounds per 1,000 cu. ft.
Pounds per 1,000 gal.	× 7.5	= Pounds per 1,000 cu. ft.
Grains per gallon	× 1.07	= Pounds per 1,000 cu. ft.

Screenings

Volume: cubic feet of screenings per million cubic feet of waste flow; range 4 to 90 for sewage.

Unit Replaced	Conversion Factor	Recommended Unit
Cubic feet screenings per million gallons	× 7.5	= Cubic feet screenings per million cubic feet waste flow
Cubic yards screenings per million gallons	× 202.5	= Cubic feet screenings per million cubic feet waste flow

Grit Removal

Volume of Grit

Cubic feet of grit per million cubic feet of waste flow; range 7 to 90 for sewage.

Overflow Velocity [5]

Feet per minute (also state depth of grit chamber in feet); range 2 to 5 for sewage.

Displacement Velocity

Feet per second (also state length of grit chamber in fact).

Detention Time

Seconds of detention time in grit chamber (grit chamber volume basis); range 10 to 100 for sewage.

Unit Replaced	Conversion Factor	Recommended Unit
Cubic feet grit per million gallons	× 7.5	= Cubic feet grit per million cubic feet waste flow
Cubic yards grit per million gallons	× 202.5	= Cubic feet grit per million cubic feet waste flow
Gallons per day per square foot	× (1/10,800)	= Feet per minute

[3] For treatment units such as trickling filters and activated sludge tanks in which another treatment step (sedimentation) is an integral part of the process, the effluent is considered to be that from the final treatment units.

[4] Conversion factors computed using (a) density of water as 8.34 lb. per gallon and (b) 7.5 gal. equals 1.00 cu. ft.

[5] Overflow velocity for grit chambers is analogous to surface overflow rate or surface loading rate for sedimentation tanks. When the commonly used unit "gallons per day per square foot of surface area" is converted to "cubic feet per day per square foot of surface area" it is readily seen that the latter unit is $\frac{\text{cu. ft.}}{\text{day}} \times \frac{1}{\text{sq. ft.}}$ or $\frac{\text{ft.}}{\text{day}}$, *i.e.*, a true velocity unit. Thus for exactness and simplicity of expression, the overflow velocity was selected as a "recommended unit." For grit chamber use, the time unit "minutes" was selected because the numbers usually employed

Sedimentation

Volume of Sludge

Cubic feet of sludge per 1,000 cu. ft. of waste flow; range 2 to 10 for sewage.

Weight of Dry Sludge Solids

Pounds of dry sludge solids per 1,000 cu. ft. of waste flow; range 3 to 15 for sewage.

Sludge Concentration

Per cent total solids in sludge; range 1 to 10 for sewage.

Overflow Velocity [5]

Feet per hour; range 2 to 12 for sewage.

Surface-Area-Weir-Length Ratio

Square feet of tank surface per foot of weir length (ft.); range 5 to 150 for sewage.

Weir Overflow Rate [6]

Cubic feet waste flow per hour per lineal foot of weir length; range 10 to 100 for sewage.

Detention Time

Hours detention time (settling tank volume basis); range 0.5 to 10 for wastes.

Unit Replaced	Conversion Factor	Recommended Unit
Cubic feet sludge per million gallons	× (7.5/1,000)	= Cubic feet sludge per 1,000 cu. ft. flow
Gallons sludge per million gallons	× (1/1,000)	= Cubic feet sludge per 1,000 cu. ft. flow
Pounds dry solids per million gallons	× (7.5/1,000)	= Pounds dry solids per 1,000 cu. ft. waste flow
Gallons per day per square foot of surface area	× (1/180)	= Feet per hour
Gallons per day per lineal foot of weir	× (1/180)	= Cubic feet waste flow per hour per lineal foot weir

Biological Filters—Trickling Filters [7]

Liquid Load [8]

Feet [9] (vertical) per day; low-rate filter range 5 to 15; high-rate filter range 15 to 100.

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were easier to handle. For comparable reasons, the overflow velocity for sedimentation tanks was chosen as feet per hour.

[5] Overflow velocity times surface-area-weir-length ratio equals weir overflow rate.

[7] Because of the large number of flow patterns possible with series operation of filters, particularly where recirculation is employed, standard expressions are not being recommended. It is recommended, however, that the same general scheme be followed for determining loadings and efficiencies of individual filters used in series as that recommended for single-stage filters in parallel. It is also recommended that for filters used in series, the over-all loadings and efficiencies be given, *i.e.*, that the two or more filters in series should be considered as one filter and the loadings and efficiencies computed as for activated sludge units.

[8] For high-rate filters, the hydraulic load includes recirculated flow.

[9] Liquid load or surface area hydraulic loadings have usually been expressed as gallons per unit area per unit time. Such a unit expresses the amount of liquid applied and thus is similar to

B.O.D. Load [10,11]

Pounds of B.O.D. per day (in waste applied to filter) per 1,000 cu. ft. of filter volume; low-rate filter range 5 to 25; high-rate filter range 25 to 300.

Recirculation

$$\text{Percentage recirculation} = \frac{\text{recirculated flow}}{\text{waste flow}} \times 100.$$

Low-rate filter range 0 to 50; high-rate filter range 50 to 1,000.

Unit Replaced	Conversion Factor	Recommended Unit
Million gallons per acre per day	× 3.061	= Feet per day (vertical)
Gallons per 1,000 sq. ft. per day	× (1/7,500)	= Feet per day (vertical)
Pounds B.O.D. per acre foot per day	× 0.023	= Pounds B.O.D. per day per 1,000 cu. ft.
Pounds B.O.D. per cubic yard per day	× 37	= Pounds B.O.D. per day per 1,000 cu. ft.

Biological Filters—Sand Filters [9]

Liquid Load

Feet (vertical) per day; range 0.3 to 1.5 for sewage.

B.O.D. Load

Pounds of B.O.D. (in waste applied) per day per 1,000 sq. ft. of surface area; range 2 to 10 for sewage.

Suspended Solids Load

Pounds of suspended solids (in waste applied) per day per 1,000 sq. ft. of surface area; range 2 to 10 for sewage.

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rainfall which is expressed in terms of the depth of water falling on the surface per unit of time. The similarity between the units is obvious when the liquid load is expressed as cubic feet of liquid per day per square foot of surface area. After dividing square feet into cubic feet, the unit is simplified to feet (depth) of liquid per day, the recommended unit.

[10] For high-rate filters, the recirculated flow is not to be considered as contributing an additional B.O.D. load.

[11] Where high-rate filters are provided with recirculation to the primary settling tank, the recirculated flow mixes with the raw waste before primary settling. The amount of B.O.D. contributed to the filter by the settled raw waste cannot be determined by a direct B.O.D. measurement and must be estimated. The following are suggested methods:

1. Settle the raw waste sample in an Imhoff cone for the same detention period provided by the sedimentation tank and determine the B.O.D. of the settled raw waste. Apply this percentage B.O.D. reduction to the raw waste passing through the settling tank.

2. Take samples of mixed raw waste and recirculated trickling filter effluent, before and after settling, and determine the B.O.D. concentrations. Apply the percentage B.O.D. reduction obtained for the primary settling tank to the raw waste passing through the settling tank.

3. Assume a standard value for the percentage B.O.D. reduction of the raw waste as it passes through the primary settling tank.

In reporting B.O.D. loadings on this type of recirculated trickling filter, the method of estimating the B.O.D. reduction of the raw waste portion by primary sedimentation should also be stated.

Unit Replaced	Conversion Factor	Recommended Unit
Gallons per acre per day	× (3.06/1,000,000)	= Feet per day
Million gallons per acre per day	× 3.06	= Feet per day
Gallons per 1,000 sq. ft. per day	× (1/7,500)	= Feet per day
Pounds B.O.D. per acre per day	× 0.023	= Pounds B.O.D. per day per 1,000 sq. ft.
Pounds suspended solids per acre per day	× 0.023	= Pounds suspended solids per day per 1,000 sq. ft.

Activated Sludge and Contact Aeration

B.O.D. Load

1. Pounds of B.O.D. applied per day per 1,000 cu. ft. of aeration tank volume.
2. For activated sludge, pounds of B.O.D. applied per day per pound of volatile solids under aeration, range 0.1 to 1.0 for sewage.
3. For contact aeration, pounds of B.O.D. applied per day per 1,000 sq. ft. of aerator contact surface; range 3 to 30 for sewage.

Air Requirements and Measurement

1. Cubic feet of air per pound of B.O.D. removed; range 300 to 1,500 for sewage.
2. Air to liquid volume ratio[12]; (air volume)/(waste volume); range 4 to 15 for sewage.
3. Cubic feet per minute air flow.

Aeration Period

Hours aeration period (based on aeration tank volume and waste flow, return sludge flow is not considered); range 2 to 24 for sewage.

Return Sludge

Per cent return sludge (return sludge flow/waste flow) × 100; range 10 to 50 for sewage.

Sludge Index

Sludge density index [13] (See "Standard Methods," 10th Edition); range 0.2 to 2 for sewage.

Unit Replaced	Conversion Factor	Recommended Unit
Cubic feet air per gallon waste flow	× 7.5	= Air-liquid volume ratio
Sludge volume index	(100/S.V.I.)	= Sludge density index

Oxidation Ponds and Lagoons

Detention Time

Days of detention time (based on lagoon volume and waste flow).

[12] Since waste flow is now also expressed as cubic feet, the unit for air measurement would be changed to cubic feet of air per cubic foot of waste flow, instead of cubic feet of air per gallon of waste flow. The unit for air flow simplifies further, however, to air to liquid volume ratio and volume units are no longer needed.

[13] The sludge density index is the per cent solids in the settled activated sludge when settled under the standard conditions of the test; namely, 0.5 hr. settling in 1-l. graduate cylinders.

B.O.D. Load

Pounds of B.O.D. per day per 1,000 sq. ft. of surface area.

Chlorination

Disinfection

1. Dosage: pounds of chlorine per 1,000 cu. ft. of waste for a stated contact time and chlorine residual; range 0.2 to 2 for sewage.
2. Residual: milligrams per liter of chlorine residual and contact time required to meet bacteriological standards.
3. Effluent quality: (a) number of coliform bacteria per milliliter remaining; (b) per cent of samples passing bacteriological standards.

B.O.D. and Odor Reduction

No special recommendation: the expressions used should be specific, preferably in pounds of chlorine per unit (pounds of volume).

Unit Replaced	Conversion Factor	Recommended Unit
Parts per million chlorine dosage	× (1/16)	= Pounds chlorine per 1,000 cu. ft.
Parts per million chlorine residual	× 1.00	= Milligrams per liter residual (also state contact time)
Percentage reduction of coliform bacteria	—	Number of coliform bacteria per milliliter remaining

Digestion

Sludge Digestion

1. Pounds of volatile solids per day per 1,000 cu. ft. of digester volume; range 50 to 1,000.
2. Days detention period (digester volume basis).
3. Percentage reduction of volatile solids.
4. Cubic feet of gas per pound of volatile solids fed.

Waste Digestion

1. Pounds of B.O.D. per day per 1,000 cu. ft. of digester volume; range 10 to 100.
2. Days detention period (digester volume basis).
3. Percentage B.O.D. reduction.
4. Cubic feet of gas per pound of B.O.D. fed.

Unit Replaced	Conversion Factor	Recommended Unit
Pounds volatile solids per day per cubic foot digester volume	× 1,000	= Pounds volatile solids per day per 1,000 cu. ft. digester volume
Pounds B.O.D. per day per cubic foot digester volume	× 1,000	= Pounds B.O.D. per day per 1,000 cu. ft. digester volume

Sludge Dewatering and Drying

Sand Bed Drying

1. Pounds of dry solids per year per square foot of bed area; range 10 to 40 for digested sewage sludge.

2. Feet (depth) per year wet sludge placed on drying beds; range 3 to 12 for digested sewage sludge.
3. Per cent dry solids in sludge cake.

Vacuum Filtration

1. Pounds of dry solids per hour per square foot of filter surface.
2. Feet per hour of wet sludge applied to filter surface.
3. Per cent dry solids in filter cake.
4. Chemical dosage to dry sludge solids ratio (per cent).

Heat Drying

1. B.t.u. per pound of sludge cake.
2. B.t.u. required per pound of water evaporated.
3. Pounds of water evaporated per hour.
4. Per cent moisture in product.

Unit Replaced	Conversion Factor	Recommended Unit
Cubic feet wet sludge per year per square foot surface area	× 1.00	= Feet per year wet sludge on drying bed surface
Gallons wet sludge per minute per square foot of filter surface	× 8.0	= Feet (depth) per hour of wet sludge applied to filter surface

Sludge Disposal

Incineration

1. Pounds of wet sludge per hour per square foot of heating surface (at specified sludge dry solids content).
2. Pounds of wet sludge per hour per cubic foot of combustion chamber (at specified sludge dry solids content).
3. Per cent carbon dioxide in exhaust gases (by volume).
4. B.t.u. per pound of moisture evaporated.

Land and Sea Disposal

Cubic feet wet solids per day, month, or year.

USPHS TRAINEESHIPS

Applications are being accepted until April 1, 1957, for public health traineeships for professional health personnel. Traineeships are available to all categories of professional public health personnel who have completed their basic professional education. Preference is given to qualified individuals, under 35 years of age, with minimum experience and technical training.

The highest academic degree held by the individual determines the basic stipend level. The annual (12-month) amounts range from $2,400 to $4,800, plus allowances for dependents and tuition. The trainee may select any institution that offers a nationally recognized graduate or specialty program in public health training in his professional field. Entrance arrangements must be made by the individual.

Additional information and application forms may be obtained from the Chief, Division of General Health Services, Bureau of State Services, Public Health Service, Washington 25, D. C., or from any regional office of the Department of Health, Education, and Welfare.

Industrial Wastes

SOURCES AND CONTROL OF RADIOACTIVE WATER POLLUTANTS *

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In addition to the many benefits resulting from the rapid development of all phases of the atomic energy industry, there has been created a series of environmental and occupational radiation exposure problems. Until quite recently, the major nuclear projects have been administered by the federal government, and the protection of workers and the public against nuclear radiations has been largely a federal responsibility. With the advent of a world-wide program to develop peaceful uses of atomic energy, the variety and magnitude of public and private uses of radioactive materials will increase greatly. The associated environmental and occupational radiological health problems will develop at a corresponding pace, and state health agencies will have to assume increased responsibility for protecting the public health in this field.

This paper will discuss one phase of the environmental contamination problem, namely water pollution by radioactive materials. In this, as well as in other phases of the larger problem, all of the agencies and individuals involved have a dual responsibility. In brief, it is to protect the public from excessive radiation exposure, while at the same time aiding in the development of a valuable new industry.

Radioactivity †

The classical picture of an atom consists of a central nucleus about which rotate a number of electrons in specific orbits, much as the planets rotate about the earth's sun. The nucleus is made up of relatively massive protons and neutrons. The proton carries a positive electrostatic charge, whereas the neutron has no charge.

Certain atoms are radioactive; that is, they have nuclei which are unstable in the sense that the physical forces within the nucleus are not well balanced. In an effort to achieve a balanced internal force condition, such nuclei emit an energetic particle (alpha or beta), or a pulse of energy (gamma radiation), or both. This process is radioactive decay.

Alpha Decay

An alpha particle is a nucleus of a helium atom, hence in alpha decay the parent nucleus loses two protons and two neutrons. The resulting daughter nucleus, therefore, is lighter by four mass units, and its total positive charge is lower by two units. For example, radium (atomic number 88, mass number 226) decays by alpha emission to radon (atomic number 86,

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† See references (1)(2).

mass number 222). The alpha particle quickly picks up two orbital electrons from the surrounding air and becomes an atom of helium gas.

Beta Decay

In beta decay, an electron is emitted by the nucleus. Electrons have very little mass, hence the mass number of the daughter nucleus is unchanged; its atomic number is increased by one unit, since the electron carries one negative unit of charge. Thus radiophosphorus (atomic number 15, mass number 32) decays to sulfur (atomic number 16, mass number 32) by emitting an electron.

Gamma Decay

Gamma decay is only the emission of a pulse of energy, hence no new nucleus is formed, but the nucleus is left in a less "excited" energy state. Thus, cobalt^{60} decays by beta emission to an excited atom of nickel^{60}. The nickel^{60} then decays by gamma emission to a less excited atom of nickel^{60}.

Chain decay occurs if the daughter product of a decay process is itself radioactive.

The amount of kinetic energy carried by an emitted radiation is specific for each radioactive isotope, as is also the half-life*. The resulting decay scheme, consisting of the type of radiation, its energy, and its half-life, is different for every radioisotope. The fact that no two radioisotopes possess exactly the same decay scheme is the basis for many of the analytical methods by which specific radioisotopes can be identified in a mixture and their concentrations determined.

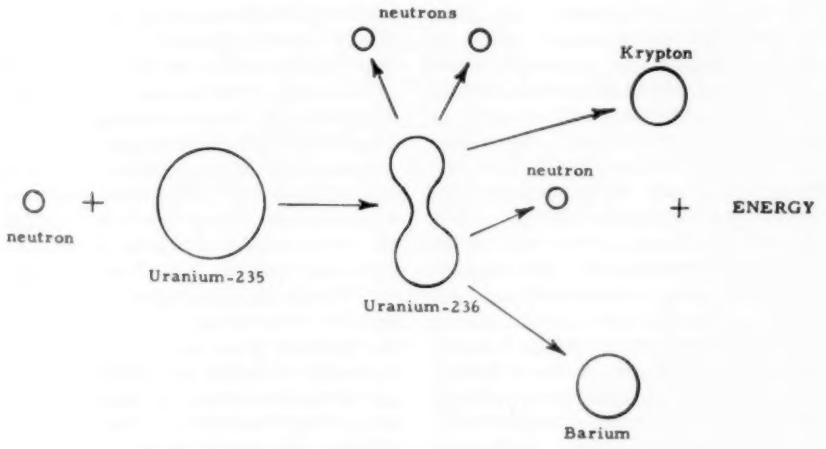
Radioactive Pollutants

The nuclear radiations ionize the medium through which they pass; molecules in their paths are hit and broken down into positive and negative ion pairs. This ionizing ability is the basis for detecting and counting radioactivity, and is responsible for the health hazard due to radiation exposure. Detection of the radiation is accomplished by instruments which measure the amount of ionization caused by passage of the radiations through a prepared medium. Exceedingly small concentrations of radioactive material can be measured. For instance, recent studies by the Public Health Service (3) involved detection of 0.2×10^{-9} p.p.m. of radium. This is 0.2 billionths of a part per million. Such levels of measurement, while new to the water pollution field, are not uncommon in the study of radioactive pollutants.

By virtue of their ionizing ability, nuclear radiations destroy or damage the living cells in the human or animal tissues through which they pass. If the source of radioactivity is located outside the body, as a nuclear power reactor, then the hazard is external. Radioactive materials which are ingested or inhaled constitute an internal hazard, because the source of radioactivity is then located inside the body. Certain elements, if ingested, tend to accumulate at specific body locations. For instance, radium and strontium accumulate in the bones, while iodine goes to the thyroid gland. If the elements involved are radioactive they will irradiate the surrounding tissue until they have decayed or have been biologically eliminated. In the water pollution field, interest is largely centered in those radioisotopes which may be ingested.

The nuclei of certain of the heavy metals (uranium, thorium, and plutonium) are so unstable that they may split into two lighter nuclei, if struck by a stray neutron. This process is nuclear fission. For instance, an atom of uranium^{235} might split into an atom of krypton and an atom of barium (Figure 1). Alternatively, it might split into two other atoms, or "fission

* The half-life is the period of time during which 50 per cent of the number of atoms initially present will decay.



$$_0n^1 + {}_{92}U^{235} \longrightarrow {}_{92}U^{236} \longrightarrow {}_{36}Kr^{90} + {}_{56}Ba^{143} + 3_0n^1 + E$$

FIGURE 1.—A graphic illustration of nuclear fission.

products." In the fission process a certain amount of the mass of uranium is converted into energy, according to Einstein's law, $E = mc^2$. Two or more neutrons are also released. In nuclear weapons, the energy released during fission results in a tremendous explosion. In nuclear power reactors, the energy of fission is converted to electric power. The fission products are usually radioactive, and are the principal source of radiological pollutants from nuclear reactors. A list (4) of the important fission products includes isotopes of all of the elements from krypton to europium.

Radioactivity is measured in activity units, or disintegrations per unit time. The basic unit of measurement, the curie, is 37 billion disintegrations per second; the microcurie (μc.) is a millionth of a curie; the micromicrocurie ($\mu\mu$c.) is 10^{-12} curies, or 2.22 disintegrations per minute. Hence the radioactivity of water may be reported as micromicrocuries per liter ($\mu\mu$c./l.) or microcuries per milliliter (μc./ml.), while that of biological or mud samples might be reported as micromicrocuries per gram ($\mu\mu$c./gm.) or microcuries per milligram (μc./mg.), etc.

Sources of Radioactive Pollutants

In considering water pollution by radioactive wastes, it is important to evaluate the relative significance of individual sources. Aside from purely local considerations, three of the major factors which determine the importance of any specific waste source are (a) the quantity of radioactive material involved, (b) the duration of the waste discharge, and (c) the hazardous nature of the specific radioisotope involved. Duration of the waste discharge involves, for instance, continuous processes as against single discharges such as radioactive tracer studies. Factors determining the hazardous nature of specific radioisotopes include (a) the kind of emission, (b) the half-life, and (c) the relative sensitivity of the human organ most affected. As an example, radium is more hazardous than radioiodine (5).

Thus, major radioactive waste prob-

lems may involve important quantities of hazardous radioisotopes which result from continuous processes. Minor problems involve the infrequent discharge of small amounts of the less hazardous radioisotopes. Obviously, the distinction may not be so clear-cut in some cases, but consideration of the foregoing criteria will provide a satisfactory estimate of the relative importance of more specific problems.

Nuclear power reactors and uranium processing plants can be major sources of radioactive wastes. Small research reactors and some radioisotope laboratories also can be relatively significant radioactive waste sources. Most medical uses of radioisotopes, infrequent radioactive tracer studies of most types, and the use of encapsulated sources are likely to be relatively minor contributors of radioactive water pollution in any specific locality. Certain types of radioisotope use such as in medicine and in research laboratories are compatible with storage and batch discharge of monitored wastes. This is a great advantage in pollution control.

Uranium Ore Refining

The initial refining of uranium bearing ores is an important source of radioactive waste. There are presently about 10 ore processing plants in operation in the western United States, and several more are being constructed.

Raw ore from nearby mines is received at these mills for the initial processing, in which the uranium is separated and concentrated. The processing steps include crushing and grinding, washing, and several chemical treatments. The final product is fused uranium salts. In this form uranium is shipped to other installations for further processing and refining, and final use.

Wastes from the ore processing may include wash waters, sands and waste solids, and various process liquors. Customarily, these liquid wastes are stored in "tailings" ponds, or lagoons, where the volume of the waste is reduced by evaporation and seepage. The tailings ponds are usually located at the edge of a stream, and wastes to the stream include seepage as well as certain direct discharges.

Uranium^{238} is the ancestor of a long chain of naturally occurring radioisotopes. It decays to thorium^{234}, which in turn decays to isotopes of protactinium, radium, polonium, bismuth, etc. Eight alpha emitters and six beta emitters occur in the main series. The end product is a stable isotope of lead. Only the uranium is recovered from the ore, and the process wastes include all of the radioactive daughters in varying amounts. Radium, which is no longer of sufficient value to warrant recovery and refining, is the most significant of the radioactive waste products. It is considered by the National Committee on Radiation Protection to be the most hazardous of all known radioisotopes, in terms of safe concentration in drinking water (5). It is a bone-seeking alpha emitter having a half-life of 1,620 years. The continuous discharge of this very hazardous radioisotope may result in excessive long-term contamination of the environment. The quantities involved and widespread nature of the problem indicate the need for careful control of the waste discharges from uranium mills.

Nuclear Reactors

Nuclear reactors for power and other purposes represent a potentially great source of radioactive waste material (4). Aside from atomic weapons, which are a special application of the fission process, there are various uses and types of reactors, including experimental research reactors, reactors used to produce radioactive materials for industrial, medical, and research purposes, and reactors for propulsion of ships and aircraft. The reactors at Hanford, Wash., are operated to produce plutonium (6), a fissionable material which does not occur in nature.

Probably the most important peaceful application of nuclear fission will be power production for civilian use. The reactor now under construction at Shippingport, Pa., is the first of a series of power reactors planned for the United States.

If enough fissionable material (uranium^{235}) is brought together in a sufficiently purified form, nuclear fission will begin and continue to occur. The extra neutrons released during fission of one atom of uranium^{235} will cause neighboring uranium atoms to fission, and the process will continue as a chain reaction. In reactors for peaceful purposes, the chain reaction is initiated and controlled so that it proceeds at a steady, safe pace.

A relatively large quantity of heat is generated during nuclear fission. Accordingly, adequate cooling of the reactor core, where the chain reaction is taking place, is a prime necessity to prevent core damage and mechanical failure of the reactor. At power installations the heat carried away from the reactor core is the source of power. For other reactor types (experimental, isotope production, plutonium production) the heat generated during fission is only a waste product.

The primary coolant may be air, water, or liquid metal. The plutonium production reactors at Hanford, Wash., are water cooled. The Oak Ridge, Tenn., installation and the Brookhaven National Laboratories, N. Y., have air-cooled reactors. The power reactor at Shippingport, Pa., will be cooled by water under pressure. Where power production is not desired, the primary coolant is a waste; at Hanford, for example, treated Columbia River water is used as the coolant, and after it has served this purpose it is temporarily stored and then discharged to the river, its radioactivity being low enough to permit this type of discharge.

There are two ways in which the primary coolant may become contaminated. Despite pretreatment, the coolant will contain impurities such as traces of metals, etc., and small quantities of corrosion products picked up in the circulation system. In passing intimately through the reactor core, the coolant will be heavily bombarded by neutrons, which "activate" stable atoms upon collision with them. Some of the impurities in the coolant will thus be made radioactive through induced radioactivity.

The coolant may also be contaminated due to rupture or failure of a fuel element in the reactor core. In design and material selection, every effort is made to prevent direct contact of the coolant and fissionable material. The uranium sometimes may be covered with corrosion-resistant metal. Nevertheless, it must be anticipated that these measures may fail, with resulting leakage of fission products and perhaps some uranium into the coolant stream. This is the most important manner in which the primary coolant may be contaminated. The quantity of fission products produced in a reactor is directly related to the power developed, and tremendous amounts of radioactive fission products are anticipated from the power industry (4)(7).

At the Shippingport, Pa., power plant the primary coolant will be continuously recirculated from the reactor core to a separate heat exchanger located away from the core, and back to the reactor. Continuous treatment of the coolant will be provided to limit the build-up of induced radioactivity; a portion will pass through an ion exchange unit for removal of impurities (8). Periodically, the primary coolant will be entirely replaced by uncontaminated water. The old coolant will be stored to allow for some decay of the radioactivity, and then it will be treated by ion exchange and gas stripping units to permit eventual safe discharge to the environment. The entire primary system is to be sepa-

rated from the conventional part of the power plant.

Two separate water systems will be located at the heat exchanger because the primary coolant will have become significantly contaminated at the reactor. The primary cooling water will flow inside many stainless steel tubes in the heat exchanger; flowing outside these same tubes will be the secondary cooling water, heated by the primary coolant. The secondary coolant will form wet steam which will then be dried and used for the production of electric power by conventional methods. After giving up its heat, the primary cooling water will be returned to the reactor to repeat the process. The possibility of direct contact between the primary and secondary coolants is thus minimized.

The fission products are impurities, and their build-up within the fuel elements of a reactor leads to reduced efficiency. Hence a reactor can be operated on a continuous basis only if its fuel elements are periodically replaced by fresh elements. The used fuel elements must then be treated for removal of the impurities and recovery of their remaining fissionable material. This involves a series of chemical separations, the waste (fission) products of which are highly radioactive.

Disposal of these highly radioactive waste products is one of the major problems presently facing the atomic energy industry. Current practice is to contain and store the wastes indefinitely in prepared underground tanks and pits, until some more practical and economical disposal method can be developed. It is anticipated that the processing of the fuel elements from the Shippingport reactor will not be carried out at the reactor site (8), but it will probably be done at one of the national atomic energy establishments. The highly radioactive fuel processing wastes, therefore, will not be a problem at the reactor site.

Other sources of radioactive waste at reactor installations will include the contaminated ion exchange resins, laundry wastes, and laboratory wastes of various kinds and levels of contamination. Various operations at the reactor plant will produce contamination of equipment and localized facilities. Wastes from decontamination procedures are also expected. Tentative plans at Shippingport include evaporation of small quantities of very "hot" wastes, storage and possible ion exchange treatment of wastes that cannot be directly discharged to the Ohio River, underground storage of spent ion exchange resin and contaminated evaporator equipment, and dilution with condenser cooling water and release to the river of low-level liquid wastes. The quantity of radioactive waste discharged to the river will be only a fraction of the permissible amount (5)(8).

Although reactors are carefully designed and constructed, the possibility of major accidents involving widespread contamination of the environment cannot be neglected (7)(9)(10)(11). McCullough *et al.* (7) state, "Of course, absolute safety is not possible, and what is really meant in connection with reactor hazards is the minimization of hazards until one has an acceptable calculated risk."

The nature of the worst accident to be planned for should be clearly defined. McCullough *et al.* (7) indicate that, "From a number of studies of possible reactor accidents of this type (nuclear runaway), it must be concluded that even though reactor accidents could happen quite rapidly in terms of human reaction times and conventional external emergency human actions, nevertheless a nuclear reactor is a very sluggish device and does not produce a nuclear explosion even remotely approximating that of an atomic bomb. Indeed, for the large thermal reactors nothing like an explosion really occurs."

The danger to people off-site is,

therefore, not the result of a serious atomic explosion. It derives rather from the possible escape of large amounts of radioactivity, and the subsequent wide dispersion of this material by meteorological effects. Thus, a chain of several unfavorable circumstances, including a nuclear runaway, possibly a resulting chemical explosion, and adverse weather conditions, is necessary before there can be an off-site threat to the population. Even though the possibility of a real off-site hazard seems remote, it is recognized and provided for in the design of the Shippingport power facility. The entire nuclear portion of that power plant is to be completely contained within a steel shell (8). This shell is designed to withstand the energy released in the worst conceivable accident or chemical explosion, thus preventing the spread of radioactivity beyond the immediate reactor site.

Stream Significance

The disposal of excessive quantities of radioactive material to streams would interfere with other legitimate water uses. Maximum allowable concentrations of radioactivity in drinking water are specified in Handbook 52 of the National Bureau of Standards (5), and are self-explanatory. If these concentrations are exceeded for any extended period of time, the water will be unsafe for human consumption. However, even though these levels are not exceeded, the discharge of radioactive wastes to rivers may result in damage to the aquatic life downstream. Plankton, fish, and other aquatic organisms will take up and concentrate certain nutrients and minerals from the river water during their life cycles. If one or more of these elements is radioactive, then the radioactivity content of the organism may be markedly increased.

Foster and Davis (6) have provided an excellent example of this from their studies of aquatic organisms taken from the Columbia River below the Hanford reactors. Among other effects, they found that radiophosphorus, one of the waste constituents, was concentrated more than 100,000 times by certain small fish in the river, even though radiophosphorus in the Columbia River water is reported to be well below dangerous levels. In interpreting the results of their studies, these authors state, "If radiophosphorus were allowed to reach the maximum level permitted for drinking water, organisms living in the water would suffer radiation damage and the fish would be unsafe for human food." Depending on the chemical properties of the specific cooling water and receiving stream, other radioactive fission products might present similar hazards (12).

The use of contaminated river water for the irrigation of agricultural land can also create a hazard of direct public health significance. Radioiodine and radiostrontium can be concentrated by plants from contaminated soil (13). In addition to the direct hazard due to consumption of plants grown under such conditions, there is also a potential hazard to animals which may graze on such herbage and to the consumers of milk products from these animals (14).

Industrial water supply is another legitimate stream use that can be impaired by the discharge of excessive amounts of radioactive wastes. Examples of industries whose process waters must be relatively free of radioactive contamination, are the food processing industry, the photographic film industry, and the atomic energy industry itself.

As an indirect effect, the discharge of warm reactor cooling waters could raise stream temperature sufficiently to cause subnormal dissolved oxygen concentrations by increasing the rate of degradation of organic wastes. This would result in a diminished stream self-purification capacity avail-

able to downstream users. High temperatures can also be directly detrimental to fish and other aquatic life.

Finally, it is advisable to consider the multiplicity of sources of human radiation exposure. Conceivably, an individual or community may in the future drink slightly contaminated water, eat slightly contaminated vegetables and fish, and breathe slightly contaminated air. A few individuals may during their working hours also ingest or inhale somewhat higher amounts of radioactive material. In evaluating the effects of any single source of radioactive contamination of the environment, it is important to examine the source in the light of all local sources of radiation exposure.

Control

The control of radioactive waste discharges to surface waters is a problem in principle no different from that encountered in the control of any other industrial waste. In this respect, radioactive wastes differ from other industrial wastes only in the minor details such as analytical methods. Although these wastes involve a very direct public health hazard, state water pollution control agencies have been dealing routinely with very similar problems for some time, and the some control measures are generally applicable. However, because of the anticipated great size of this industry and the circumstances responsible for its early development, the user of radioisotopes in any form will be regulated by federal as well as state and local agencies. This should in no way interfere with sound waste control according to well established practices and principles of sanitary engineering and public health.

Basinwide Planning

It is considered especially important that radioactive pollution be controlled on a basinwide basis insofar as possible. A great deal of information remains to be acquired about the effects of radiation exposure on aquatic and human populations, including both immediate and long term or chronic effects. In any river basin there may exist or develop a number of sources of radioactive pollution. For instance, there might develop one or several nuclear power reactors, a national establishment such as Oak Ridge National Laboratory or the Fernald, Ohio, plant, a research reactor at a university, radioisotopes research laboratories, and various medical uses of radioactive materials. The industry-by-industry approach to control of such a group of pollution sources is not likely to prove adequate. A basinwide list of all users of radioactive material should be developed, and should include federal as well as private and other sources. Such a list, kept current, can serve as a sound basis for basinwide pollution control. Existing and proposed new waste sources can then be properly evaluated in terms of their effect on the surface waters and water uses of the entire river basin.

Early Planning

Effective control of pollution requires that the state and local regulatory agencies concern themselves with a potential pollution source in the very early stages of planning. This is especially important in the case of radioactive waste sources. The state and local regulatory agencies should examine each proposed new source of radioactive pollution in terms of (a) proper site selection, (b) kinds and quantities of waste involved, (c) consequences of accidental discharge, (d) downstream water uses, (e) adequacy of proposed treatment and precautions, and (f) other influencing factors. Water monitoring after the fact cannot provide adequate protection, and the aforementioned examination should be a necessary condition to approval of the proposed radioisotope use before the industry is installed at a given location.

Where major quantities of radioac-

tivity are involved, responsible state and local agencies should consider emergency planning for potential accidents in each case. In spite of extensive precautions to avoid accidents, there is always the possibility that major radioactive discharges to the environment may occur. It is believed highly desirable that there exist a fully developed, integrated plan of action for dealing with such emergencies. Direct and rapid communication with management of the major installations should be a part of such a plan.

Stream Monitoring

Three kinds of samples are of importance with regard to radioactivity measurements in natural waters. These are (a) water, (b) biological, and (c) river mud or silt samples. Grab samples of river water will provide an instantaneous picture of stream water quality. At stream locations above any source of radioactive waste, a reasonable number of samples can yield a necessary and adequate estimate of background radioactivity. At locations downstream from waste sources such as uranium mills or nuclear reactors, abrupt hourly and daily changes of the radioactivity in the flowing water must be expected. At these locations water samples composited over a period of time can provide a more integrated measure of quality. Taken alone, grab samples of river water are not an adequate representation of downstream water quality.

River biota and mud samples reflect more than a momentary condition, and are cumulative. The stream biota (plankton, bottom animals, and fish) will take up and selectively concentrate certain chemical elements in the course of their metabolic activities, the case involving radiophosphorus having already been noted. Hence, elements which are present in reactor cooling waters, and which become radioactive due to neutron bombardment, or fission products which escape into the reactor cooling water, may appear in concentrated form in the downstream biota. The degree of concentration will depend in part on the element and the chemical form in which it occurs, as well as on environmental factors.

Samples of river biota are likely to yield data related more to soluble than to suspended radioactivity. However, it is difficult, if not presently impossible, in many cases to distinguish conclusively between radioactivity which has been adsorbed and that which is truly absorbed and metabolized. This question is of interest, for example, with regard to the radium discharged from uranium refining plants. In either case, the material becomes an intimate part of all of the biota concerned in the natural food cycles of the stream. Depending on local stream flow, temperature, hydraulics, and available food, biological samples can yield a cumulative picture of stream quality in terms of radioactivity representing a relatively long period of time. The biota can be an especially useful index of the extent of recent radioactive waste discharges from nuclear reactors.

River mud or silt samples may reflect many weeks of accumulation of insoluble suspended radioactivity, depending on the hydraulic characteristics and recent flow history of the stream. Such samples, therefore, yield information not readily obtainable by other means, and they have proved especially useful when obtained below radioactive pollution sources such as uranium mills.

Normal background radioactivity of the streams of a basin, including the three types of samples mentioned previously, is necessary information for the purpose of controlling pollutional sources, and should be obtained as soon as possible. Presently employed standards (5) for permissible gross amounts of radioactivity in water refer to amounts above the normal back-

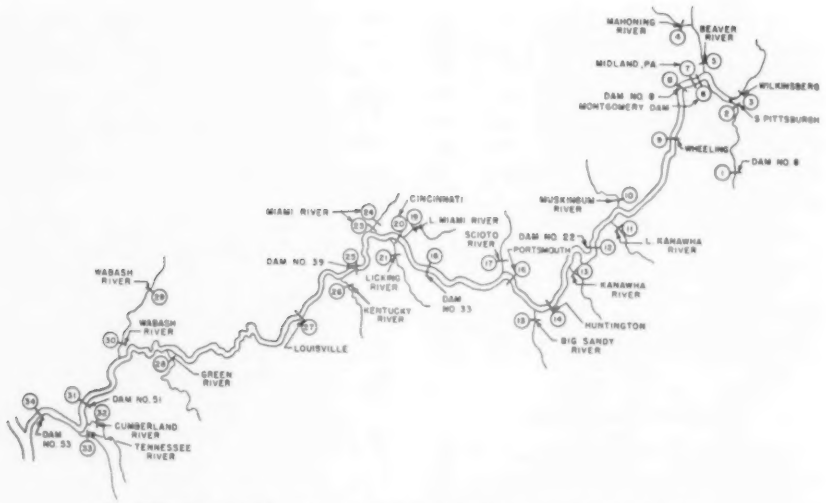


FIGURE 2.—Ohio River Basin radioactivity monitoring stations.

ground, or to the amount which can be added, rather than to total radioactivity content. These standards are not greatly in excess of natural background levels. Standards for specific radioisotopes refer to total amounts rather than to additions to the natural background. In order that the standards may be properly applied, it is necessary to have information on the normal background; this can be obtained most effectively before pollution starts. The regulatory agency should have at its disposal prior knowledge of existing users of radioisotopes and of the types of waste involved. With this information the agency will know where stream monitoring will be most useful in obtaining background as well as control information. In addition, the establishment of a water monitoring program by the state can do much to dispel public fear and apprehension.

Indiscriminate stream monitoring is not suggested. Rather, monitoring should be specific as to location and purpose. For this reason, the state water pollution control agency is best able to plan the necessary monitoring and protective action.

Ohio River Survey

Two examples of recent radioactivity background surveys in which the Public Health Service has participated may be of interest. In cooperation with the Ohio River Valley Water Sanitation Commission, a radioactivity background survey of the main stem Ohio River was made during 1956. This initial survey involved approximately 100 samples, of which about one-half were water samples and 25 per cent each were biological and mud samples. Figure 2 is a map of the river basin involved, showing the location of sampling points. Nearly one-half of the samples were collected from the main Ohio River, with the remainder from near the mouths of major tributaries. Some of the water samples were composited over a week, with daily collection, but the majority were grab samples.

Collection of samples was undertaken jointly by the Public Health Service, the states involved, and the U. S. Army Corps of Engineers. All samples were assayed for gross alpha and beta radioactivity content in suspended and dissolved form. The bio-

logical samples consisted mainly of plankton, although bottom animals were also collected when possible. No fish samples were involved in the initial survey. Also, the Public Health Service and the Pittsburgh Area Office of the Atomic Energy Commission cooperated with regard to water monitoring in the immediate vicinity of the Shippingport, Pa., nuclear power plant.

The final results of the survey should give an initial rough estimate of background radioactivity of the main Ohio River, especially in the vicinity of Shippingport, Pa., as of 1956. Certain of the tributary streams have existing atomic energy establishments, and the survey will also provide a rough indication of their effect, if any, on the quality of Ohio River water. Additional background data have been gathered at specific locations by certain of the basin states, and it is expected that further data will be gathered. With this information it will be possible to measure the effect of radioactive waste discharges from existing and new sources as they develop.

Cheyenne River

As a second example, a joint background survey of a specific section of the Cheyenne River in South Dakota has been completed by the Public Health Service and the South Dakota State Health Department. Figure 3 is a map showing the pertinent river section and location of sampling points. Operation of a new uranium mill near Edgemont, S. D., was expected to start during the summer of 1956, and the purpose of this survey was to establish radioactivity background information before the mill operation started. Angostura Reservoir is a recreational lake, the headwaters of which are about 35 river miles below the mill site.

River water, mud or sand, and plankton samples were collected at the

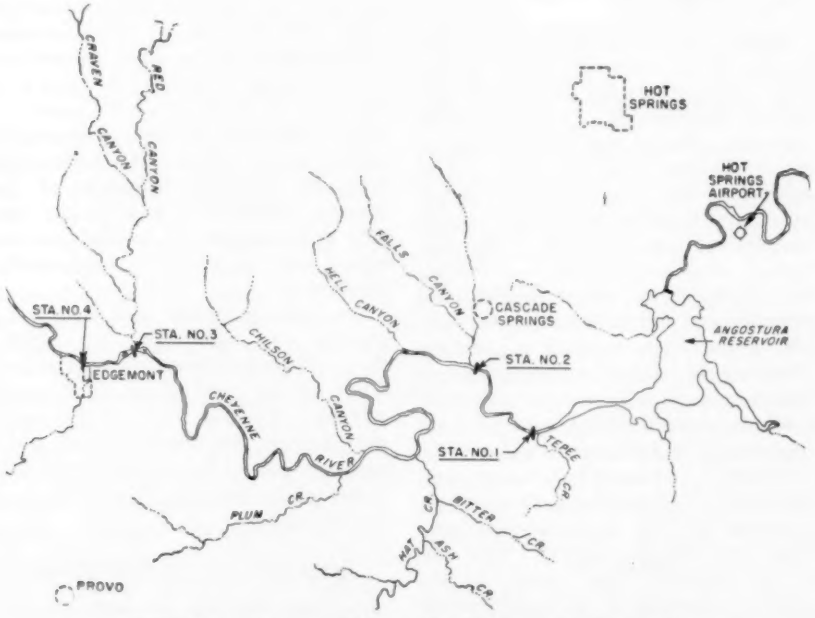


FIGURE 3.—Cheyenne River radioactivity monitoring stations.

four sampling stations. Other samples taken at the time of the initial survey included algae, minnows, and other biological forms. At a later date fish samples were collected. The water samples were analyzed for dissolved and suspended gross alpha and beta radioactivity, and mud samples for gross alpha and beta radioactivity. Biological samples were prepared in various forms according to the type of sample and mode of collection, and they were assayed for gross radioactivity.

This survey has provided the necessary basic background radioactivity data before mill operation. Further regular monitoring will provide the additional data necessary for evaluation of the effects of the uranium concentrating plant on the quality of the stream. It may also prove desirable at a later date to determine the radium content of the several types of samples, as this is the most hazardous radioisotope involved.

Columbia River

Studies of the quality of the Columbia River near Hanford, Wash., have been conducted by the Public Health Service (15), and exemplify extensive stream monitoring near a major nuclear establishment. These studies extended over a period of two years, and involved all of the types of samples previously discussed. The biological samples included plankton, filamentous algae, bottom animals, and juvenile and adult fish, and the several types were assayed separately. Chemical separation and radioassay of certain groups of elements were also made, in order to follow specific waste components in the river samples.

Natural radioactivity background levels are the baseline against which increases will be measured for purposes of pollution control. Nor can it be expected that these "background" amounts of radioactivity will remain unchanged over the years; radioactive fallout from necessary military weapons tests has already increased environmental radioactivity levels somewhat, and further slight increases may occur. Hence, in the regulatory program it will be necessary to make periodic checks of existing background information. In addition, routine stream monitoring below known major sources of radioactive contamination will be necessary.

It is clear that gross radioactivity measurements alone cannot always be adequate for purposes of pollution control. When gross radioactivity levels equal or exceed permissible limits, it will be necessary, whenever possible, to identify and measure the most important specific radioisotope involved (5). Radium, for instance, has been indicated in the case of uranium mill wastes. Strontium and cesium are specific radioisotopes of importance as fission products, and occur in connection with reactor wastes. Radiophosphorus has been incriminated also as an important waste by-product of reactors. Therefore, effective radioactive waste control will at times require identification and separate measurement of specific radioisotopes in a mixture. Most frequently this can be accomplished on the basis of the radioactive decay scheme, in combination with the chemical processing of the sample. Methods of analysis for specific radioisotopes of current interest either exist or are in process of development.

As both biological and river mud samples are cumulative by nature, they will contain more radioactive material, gram for gram, than water samples. For the purpose of specific radioisotope identification and measurement they offer a more fruitful source of information than do the water samples.

Standards and Safe Practices

A great deal is still unknown regarding the take-up of radioactive

material by living organisms and the physiological effects on humans (16). Experimental research to answer many of the basic questions is being carried out by many investigators, and the required information is certain to be developed. However, the many uncertainties still remaining make it quite undesirable at present to adopt permanent or rigid standards for the control of radioactive water pollution.

The National Committee on Radiation Protection, after weighing all available information, has developed a set of safe concentrations of radioisotopes in the environment and in the human body. These are the "Maximum Permissible Concentrations" (M.P.C.) published in Handbook 52 of the National Bureau of Standards (5). These standards are for continuous, lifetime exposure, rather than for short-term discharges or concentrations. They represent the best available knowledge, gathered and interpreted by a large group of highly qualified individuals. It is expected that the standards will be revised from time to time as better information is developed, and a first revision is expected in the near future.

In lieu of adopting permanent standards for the radioactivity content of natural waters, it is suggested that the various regulatory agencies make use of the M.P.C.'s as developed and revised by the National Committee on Radiation Protection. These suggested standards can serve adequately as temporary or interim guides for the judgment of individual situations until it becomes possible to adopt more permanent standards based on adequate knowledge.

Each source of radioactive water pollution represents an individual problem to be solved in terms of a specific location. What has been or may in the future be considered safe practice in one area may be completely unsatisfactory elsewhere. In each case, the type and quantity of waste involved, environmental factors, and existing and planned water uses are all important. These factors will determine treatment and/or storage requirements, and safe practice. As an obvious example, a reactor located in an isolated area might be allowed more latitude as to waste discharges than one located in a heavily populated area. What is acceptable and safe in the first case might be highly undesirable in the second. Even in quite isolated areas, however, there must be well-defined limits of environmental contamination, so that the possibility of developing presently unused resources at some future time is not reduced or eliminated.

The National Committee on Radiation Protection has stated (5) the following excellent philosophy with regard to radioactive waste discharges:

"Because of the many uncertainties involved, this Committee recommends that every effort be made to keep the concentrations of radioisotopes in air and water and in the body to a minimum. The goal should be **no** radioactive contamination of air and water and of the body if it can be accomplished with reasonable expense and effort. If such a goal cannot be attained, the average operating levels should be kept as far below these recommended values as possible, and not above them for any extended periods of time."

Clearly, then, the maximum permissible concentrations are not concentrations to be aimed at and even exceeded a little. Quite the contrary. They are permissible amounts estimated on the basis of expert judgment and, at times, inadequate knowledge. They are definitely not desirable amounts of radioactivity in the environment.

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PUBLIC LAW 660—ACTIVITIES

First construction grants under the new Federal Water Pollution Control Act were granted early in November, 1956 to Higginsville, Mo., and Meridian, Miss. The estimated cost of the Higginsville project is $521,000, the Federal share being $146,888; and the Meridian facility, $1,992,100, with the Federal share $250,000. Individual grants are limited to $250,000, or 30 per cent of the estimated cost, whichever is less.

The first public hearing on interstate water pollution was held in January, 1957 at Homer, La. Evidence was received on allegations that Arkansas oil wells are discharging acid, salt, and other wastes into water flowing into Louisiana.

DAIRY WASTE DISPOSAL BY SPRAY IRRIGATION *

By Frank J. McKee

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Disposal Problem

The dairy industry in the United States includes a large number of small plants located in rural areas convenient to the source of milk supply. Originally these plants served the farmers in the immediate area and were so small in size that there was no undue concentration of waste to cause nuisances. In recent years, however, there has been a definite trend towards reduction in the number of dairy plants and an increase in plant size and the per-plant production. This has resulted in a concentration of dairy wastes in these larger plants to the point where public nuisances and stream pollution have resulted.

Many of these plants are still located in rural areas and small towns where adequate waste treatment facilities are not available. Plants which are located in large cities normally do not have a problem in disposing of wastes to the public sewers. The separate treatment of dairy wastes by various methods has been developed by the rural and small town plants where treatment with municipal wastes has not appeared desirable from either an engineering or a financial standpoint.

Trickling filter and aeration-type treatments of dairy wastes have been attempted and found reasonably successful (1). However, in recent years the cost of constructing such plants has mounted steadily and has now reached the point where construction costs are $200 per pound of daily B.O.D. capacity (2). There is a considerable fluctuation in the strength of dairy plant wastes, particularly in the case of cheese factories where the by-product, whey, is of very low value and may at times be discharged with the processing waste. Most industrial operations encounter similar problems; a treatment plant must of necessity be built for the maximum daily load which may be several times the average load. At cheese factories, waste treatment by the conventional methods has not been found entirely satisfactory. The addition of any amount of whey to the usual dairy plant wastes increases the B.O.D. and also decreases the ratio of nitrogen to B.O.D. to a point where normal biological treatment does not completely oxidize the wastes.

A typical analysis of cheese factory process wastes and whey is shown in Table I. Of particular interest is the fact that the ratio of nitrogen to B.O.D. in both the waste and the whey is about 1 to 24, whereas in domestic sewage the ratio is about 1 to 7. The sodium content is high, indicating the loss of salt from the plant.

The waste from the cheese factory (Table I) was discharged to a spray-irrigation system at the rate of 8,770 g.p.d. Milk intake was 132,500 lb. per day, and only a small amount of whey was discharged with the plant waste to the spray field. The analysis of the whey is included in Table I to show that appreciable amounts of whey can cause a considerable increase in the B.O.D. and the total organic solids content of the waste. The nitrogen, phosphorus, and potassium have defi-

* Presented at 29th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Los Angeles, Calif.; Oct. 8–11, 1956.

TABLE I.—Analysis of Cheese Factory Wastes and Whey[1]

Item	Process Wastes (p.p.m.)	Separated Whey (p.p.m.)
Nitrogen:		
Total organic	73.2	1,300.0
Free ammonia	6.0	31.0
Solids:		
Total	4,516.0	54,772.0
Fixed	1,818.0	5,160.0
Volatile	2,698.0	49,612.0
Soluble	3,956.0	54,656.0
Suspended	560.0	116.0
B.O.D., 5-day	1,890.0	30,100.0
Sodium	807.0	648.0
Calcium	112.5	350.0
Magnesium	25.0	78.0
Potassium	116.0	1,000.0
Phosphorus	59.0	450.0
pH	5.7	6.2
Temperature (° C.)	37.5	—

[1] Reference (3).

nite values as fertilizer, in addition to the value of the water for irrigation purposes.

As a result of unsatisfactory experiences with conventional types of waste treatment plants for cheese factories and the rising cost of constructing them, an effort was made to develop an alternate method which would be both less expensive and more satisfactory. The use of spray irrigation, as originally started in the canning industry, was attempted and found to be successful (4). Construction costs are relatively low and the system has particular application in rural areas and small communities where vacant land is available adjacent to the plant.

Plant Piping

Experience has shown that waste volume, rather than concentration, is the limiting factor in determining the area of land needed for spray irrigation disposal.

Separation of Wastes

The first step in installing a spray-irrigation waste disposal system is the separation of all clear cooling waters and rain water from the floor water and wash waste. It is also desirable to eliminate sanitary sewage from the dairy waste. The second essential to the proper operation of a spray-irrigation system is the rigid control of the amount of wash water used.

In the case of new plants, the sewer system should be laid out in three parts so that complete separation is made between (a) rain water and cooling water, (b) sanitary sewage, and (c) process wastes. The rain and cooling water which is uncontaminated can be discharged to a water course or storm sewer, the sanitary sewage to a septic tank or sanitary sewer, and the process waste to the spray-irrigation system.

Water Usage Control

The control of water usage within the plant is best done by providing equipment which prevents the wasting of water. Extensive use should be made of automatic shutoff nozzles on wash-up hoses. These nozzles will close automatically when they are released by the operator. A desirable procedure is to install a tempered-water distribution system in which warm water of the proper temperature for washing equipment is distributed through the plant in a single pipe system. Hanging hoses are connected to an overhead distribution system and the hoses are installed alongside equipment with the nozzle hanging just above the floor. In this way the volume of water can be reduced to a minimum and, at the same time, the washing operation is made more thorough through the ready availability of wash-up hoses. Several types of automatic shutoff nozzles have been used successfully.*

The actual volumes of water discharged from dairy plants can be reduced to unusually low amounts by proper installation of sewers and

* Strahman nozzles and Lonn nozzles.

water-saving equipment. The education of plant personnel, while important, is secondary to the providing of adequate equipment to save water. Plants have been successful in reducing waste volumes to as low as 350 gal. of water per 10,000 lb. of milk intake. However, the average waste volume is approximately 1,000 gal. per 10,000 lb. of milk intake.

Spray-Irrigation System

Screening

The waste-process waters are conducted to a sump at a convenient location where they are pumped to the spray-irrigation field. It is desirable to provide settling or fine screening for the waste prior to its entering the pump sump. In several installations this has been done by passing the waste through a small settling tank or by hanging a screened basket below the sewer inlet to the sump. Sometimes both methods are employed. Figure 1 shows a pump sump with a basket screen through which the wastes fall before entering the sump. Also shown is the float switch for controlling the pump in the adjacent dry pit. Normally, where floor drains with baskets are installed in the plant, the amount of waste collected on the screens is small.

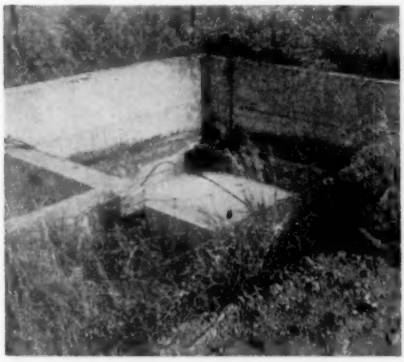

FIGURE 1.—Dairy waste sump with basket screen.

Pump Installation

The pump sumps are usually designed to provide for not less than 20 min. operation of the waste-spraying pump per cycle. The pumps for spraying the waste should be sized for the particular sprinklers in use. Sprinklers may require a pressure of 30 to 60 p.s.i. at the nozzle and discharge from 10 to 75 g.p.m. Accordingly, the pump should be selected for the proper pressure and volume, and the pipe friction and differences in elevation must be taken into account.

To produce the desired pressure, the pump should be of the open impeller type which normally operates at 3,600 r.p.m. In some installations, the pump has been installed above the pit which, of course, results in a suction lift of the waste to the pump. This is not completely satisfactory because of possible loss of prime and resulting failure of the pump. However, self-priming pumps have been used in this way with good success and the method has value in small systems because of lower cost. On larger installations the pumps are set in a dry pit, taking suction through the pit wall from the adjacent wet pit. In this way the pumps are provided with a positive suction head, resulting in much more reliable operation. A stand-by pump is desirable but many installations operate with only one pump.

Distribution Piping

The distribution piping from the pump to the sprinklers can be installed above the ground where summer operation only is anticipated and below ground where year-round operation is intended. The depth to which the pipe should be buried depends on the local frost conditions. It is desirable to install the pipes so that drainage will be obtained either to the pump pit or to drain valves installed in low points in the piping. The drain valves used on water hydrants have been used

FIGURE 2.—Aluminum irrigation piping and spray sprinklers.

successfully for draining the underground laterals and mains of the spray-irrigation system.

The Skinner ¾-in. sprinkler, which has a single nozzle approximately 5/32 in. in diameter, has been used successfully. Some difficulty has been experienced with plugging of these nozzles. Usually, however, four or more of the smaller nozzles are in use at the same time and the occasional plugging of a nozzle is not a serious deterrent to their use.

There are the two types of distribution piping in general use; moveable and permanent. The overground aluminum irrigation pipe (Figure 2) is used where it is intended to move the pipe and sprinklers manually from place to place and where winter operation is not intended. The sprinklers are mounted directly on the piping.

The permanent piping system is installed under the ground below the frost line. Galvanized wrought steel pipe has been found satisfactory, although cast iron has been used in some installations. In order to reduce the amount of piping, a small number of large sprinklers are used. The Rainbird No. 80S sprinkler has been used successfully. This has a double nozzle with openings 9/16 in. and ¼ in. It discharges 73 g.p.m. at 50 p.s.i. at the nozzle and can cover an area 180 ft. in diameter or 0.58 acres.

Figure 3 shows such a sprinkler installed on a tripod stand. The tripod increases the area covered by the nozzle only slightly and is not necessary. The sprinkler is usually installed about 2 ft. above the ground. The choice of large nozzles is also dictated by the necessity of having the nozzle openings as large as possible to reduce the possibility of plugging, since only one or two sprinklers will be in operation at a time.

Typical Installations

One of the first recorded uses of waste disposal by means of spray irrigation was at Donaldson, Tenn., in 1949. This installation handled 12,600 gal. of waste through a 2-in. line. A 5-h.p. centrifugal pump served two spray nozzles which were moved daily and covered two acres in 10 days. The average concentration of the waste was 70 lb. of B.O.D. per day.

The next installation of record was

FIGURE 3.—Sprinkler installed on a tripod.

installed in 1951 at a dairy near Camden, N. J. and designed for spraying 75,000 gal. per day on 45 acres. A pump sump capable of holding five to six days of waste was apparently too large and resulted in an odor nuisance and a rather unfavorable operating impression.

Pickerington, Ohio

At Pickerington, Ohio, dairy wastes were originally lagooned, resulting in an odor problem. In 1952 an installation was made to spray the lagoon waste onto pasture land. However, the odor nuisance persisted and in 1953 the installation was changed to spray fresh waste directly to the field. This installation was much more satisfactory. The waste was pumped through an underground line 4-in. in diameter and discharged through one of 9 2-in. spray nozzles. The pasture drain tiles were plugged in order to prevent the discharge of strong wastes to an adjacent stream. Cows were pastured in the field while the spray operation was in progress. Only one nozzle was used at a time and the spray location was changed daily. There was an excellent growth of grass in the pasture. In extremely cold weather, the lagoon was used rather than the sprays.

Bridgeton, N. J.

An installation made at Bridgeton, N. J., in 1950 discharged wastes by gravity to an open sump pit where a 300 g.p.m. centrifugal pump was installed. Overground aluminum pipes were used for headers and laterals with spray nozzles located every 40 ft. During the "flush" season 75,000 g.p.d. were sprayed on the area and one lateral was moved every three days. Thereafter the pump was run only about 3 hr. per day. The installation was originally designed for 100 acres, but actually only three 10-acre fields were used. The system operated daily even during the winter, although a heavy ice covering formed on the ground and fences. The lines are drained at the low points and there has been no freezing trouble. The milk plant bottles about 35,000 lb. of milk daily and makes about 1,000 lb. of cottage cheese each week. Caustic solution is drained from the bottle washer every three months to floor drains and the dilution afforded by the day's waste volume has prevented any ill effects on the vegetation of the spray area.

Berwick, Ont., Canada

The first Kraft Foods Company installation was made at Berwick, Ont., in 1952. This installation sprayed about 8,000 gal. of waste per day through two spray nozzles, which were moved weekly and covered an area of approximately three acres. Plastic pipe, laid above ground, was used for part of the installation and galvanized wrought steel pipe for the remainder. The spray nozzles were placed on risers 6 ft. above the ground surface and the spray circle was approximately 100 ft. in diameter. During the winter the sprays were not used and the waste was discharged through a large septic tank. This installation was successful in preventing odor complaints and eliminating stream pollution during periods of low stream flow in the summer months.

Alexandria, Tenn.

A spray-irrigation installation at Alexandria, Tenn., in 1953, consisted of six spray nozzles located in a field approximately 3.5 acres in area. Wastes were drained by gravity from the dairy plant to a sump pit and then pumped through a header to laterals in the field. The header was galvanized pipe installed approximately 18 in. underground and the laterals were polyethylene plastic pipe laid above ground. This installation successfully disposed of plant floor washings and occasionally some whey.

The original thin top soil developed into a heavy rich soil with a luxuriant root structure of the grasses grown on the field.

Shirley, Ind.

At Shirley, Ind., a spray-irrigation installation was designed for year-round operation by burying all of the galvanized wrought steel headers and laterals approximately 30 in. deep. Approximately 10 acres were available, of which about six acres were provided with underground piping for spray nozzles. The spray nozzles were selected to cover a circle 100 ft. in diameter and they were spaced approximately 90 ft. apart. Two spray nozzles were used at a time to provide a discharge of approximately 100 g.p.m. In addition to the underground system for floor wastes, an overground system covering approximately two acres was installed for the disposal of approximately 5,000 lb. of whey daily on an experimental basis. The whey killed the grasses but it did develop a very prolific growth of weeds.

Some difficulties were encountered due to the discovery of underground drain tiles in the field after the installation was made. It was necessary to plug this tile system to prevent too rapid discharge of the wastes into the receiving stream.

Owenton, Ky.

A spray irrigation system at Owenton, Ky. alleviated a very difficult waste disposal problem. In this instance, the receiving stream was so small that 100 per cent purification would be necessary to prevent a nuisance condition. A spray-irrigation system, which eliminated the discharge of the waste to the stream, was probably the only method that would be suitable. Because of steep slopes, only about 6 of the 10 acres of available land were useable, and the sprinklers had to be changed frequently to prevent runoff.

Milan, Wis.

At Milan, Wis. an above-ground installation operated during the summer months. When truck weight limitations on the highways prevented the hauling of whey, the spray-irrigation system was used to dispose of whey as well as process wastes. Loadings up to 100,000 lb. of whey per day were sprayed during a period of two months. As a result, the vegetation was killed, the ground became covered with fungus, and much of the waste ran off (Figure 4). Since then additional land has been obtained to permit spraying over a greater area.

Others

Recently, many small installations, having a daily milk intake in the range of 15,000 to 30,000 lb., have been placed in operation throughout the State of Wisconsin. These installations are quite similar and consist of a concrete pump sump, a centrifugal pump, and sectional aluminum piping laid above ground. Small sprinklers are installed on the top of the aluminum pipe at approximately 40-ft. intervals. The pump discharges 30 g.p.m. at 20 p.s.i. The cost of these

FIGURE 4.—Spray-irrigation field showing effects of excessive whey discharge.

installations averages about $1,600 for a waste volume of approximately 2,000 g.p.d. The wastes are sprayed on pasture land and have promoted the growth of the grass.

A simple system may consist of the waste sump and pump which discharges through a 2-in. aluminum line directly to the ground without benefit of spray nozzles. Some grass is killed within a few feet of the point of discharge and there is some runoff. The area used was about one-half acre in extent and the flow of waste amounted to about 2,000 g.p.d. Such an operation can successfully dispose of the dairy waste.

Land Area

The first problem which arises in designing a spray-irrigation system concerns the area of land necessary to provide the proper treatment. Table II summarizes the dosage used at the previously discussed dairy plants. Waste volume rather than B.O.D. content appears to be the most important consideration. There are a number of factors which influence the dosage of waste on the spray-irrigation field. The three most important are: (a) the slope of the ground, (b) the type of soil, and (c) the type of cover crop.

Slope

The slope of the ground should preferably be less than 6 per cent and the land should be relatively free from gullies. The most ideal condition is to have the land slope gradually, and the pump located at a low elevation with the sprinklers installed up hill in such a manner that the piping will drain back to the sump when the pump is not operating.

TABLE II.—Dosage Rate of Spray Irrigation Systems

Plant Location	Waste Per Day (gal.)	Spray Area (acres)	Rate of Application (g.p.a.d.)
Donaldson, Tenn.	12,600	2	6,300
Camden, N. J.	75,000	45	1,670
Bridgeton, N. J.	75,000	30	2,500
Berwick, Ont., Canada	8,000	3	2,700
Shirley, Ind.	10,000	6	1,670
Milan, Wis.	6,000	2.5	2,400
Owenton, Ky.	25,000	6	4,200

Soil

The type of soil influences to a great extent the volume of water that can be discharged on it. Clay soil, of course, does not absorb water as rapidly as loose loam or gravelly soil. Furthermore, clay soil has the property of acting as a base exchange material and will exchange the calcium normally present in clay soil for the sodium present in the waste. If the clay soil becomes loaded with sodium, it loses its ability to absorb water and becomes exceedingly hard. When this happens, vegetation will not grow and the spray-irrigation field is ruined. The limits for sodium which have been suggested are 100 p.p.m. On clay soils, it is recommended that the spray field be given an occasional treatment with agricultural lime in order to compensate for the effects of the sodium in the waste.

Vegetation

The type of vegetation has some importance in determining the water absorbing characteristics of the soil. Experience has shown that grasses are most satisfactory for dairy wastes. Reed's canary grass has been recommended as being the best cover crop. It is believed that the difference in the grasses is relatively minor and that any good grass cover crop is satisfactory. It takes approximately two years to obtain a good cover crop and develop the maximum absorption capacity. Accordingly, a field already planted in grass is the most desirable.

Winter Operation

Winter operation of spray-irrigation systems is a subject of considerable interest. The facility at Shirley, Ind., has operated throughout the winter for three years and has not encountered any extreme difficulties. Some trouble has been experienced with

frozen nozzles. The best remedy has been to remove the nozzles and thaw them out. During extremely cold weather the waste freezes on the ground and does not run off to any great extent. The most difficult period of operation is in March when there are periods of alternate thawing and freezing. During this time there will be runoff from the field which will contain incompletely treated waste. The field is normally saturated with water due to melting snow and, since the grass has not started to grow, there is little opportunity for transpiration. Some of the waste is absorbed into the ground even under these conditions and, in passing over the ground, the waste receives some treatment so that when it reaches the water course it is considerably less objectionable than the raw waste from the factory. This period of incomplete treatment appears to last only about a month and as soon as the grass begins to grow, the runoff ceases.

Disposal of Whey

The spray-irrigation system has been found to be the most satisfactory method of cheese factory waste disposal. In normal operation, a certain amount of whey is discharged to the sewer and, under some conditions, this can be substantial.

The whey is nutritionally unbalanced, being deficient in protein and nitrogen. Accordingly, the bacteria which normally operate in a conventional waste treatment system do not have sufficient nitrogen to completely oxidize the waste material. The result is unsatisfactory operation of the conventional waste treatment plant. In the case of spray irrigation, this difficulty is not nearly as prevalent. The soil contains nitrogen to provide for the decomposition of considerable amounts of whey and, since the nitrogen remains in the soil, the system seems to operate more or less indefinitely.

Experience has indicated that a spray-irrigation system will operate successfully with considerably more whey in the waste than can be tolerated in a trickling filter or activated sludge treatment plant. If large amounts of whey are discharged to the spray-irrigation system, it does affect the grass and the tendency is for weeds to grow in place of the grasses. Apparently weeds can thrive on less nitrogen than the grasses. Excessive whey will kill all vegetation.

Conclusion

The disposal of wastes from dairy plants by spray irrigation has proved most satisfactory. In addition, many of the operating problems associated with the usual methods of dairy waste treatment have been elimniated. Stream pollution problems have been reduced and pasture land has been improved.

Irrigation systems usually comprise a collecting sump, pumping equipment and a distribution system equipped with sprinklers. Cast iron pipe is used for permanent, buried distributors, and aluminum pipe for portable systems. Spray heads may be attached directly to the pipe or mounted on risers. Winter operation requires a buried distribution system.

Application of the wastes varies from 2,500 to 10,000 g.p.a.d., depending on the type of soil and vegetation. Under normal conditions, there is no runoff or odor nuisance.

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PACKINGHOUSE WASTE TRICKLING FILTER EFFICIENCY FOLLOWING AIR FLOTATION *

By Karl A. Hirlinger and C. E. Gross

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The objective of this study was to determine the efficiency of a trickling filter in reducing the 5-day B.O.D. of packinghouse waste which had previously been subjected to treatment by air flotation.

Test Filter

Since the bulk of the solid materials would be eliminated from the packinghouse waste by the flotation process, a small-scale barrel-type trickling filter would not be satisfactory for test purposes. Accordingly, a 14-ft.diameter filter was designed and constructed to obtain data which would be of practical value in determining the size of full-scale units in possible future planning. The filter was designed in accordance with the formula advocated by Eldridge (1) for high-rate trickling filters.

The trickling filter (Figure 1) was fabricated on the roof of the building housing the air flotation unit to facilitate the sampling and handling of the flows to and from the filter. The walls of the filter were made of 2-in. by 6-in. wooden planks. The filter media was extruded clay tile of a type commercially available. Total depth of the media was 6 ft. The waste fed to the filter was distributed by a rotating propeller-type distributor driven by an electric motor. The entire trickling filter system was mounted on 8-in. by 8-in. wooden sills, laid parallel to form drain galleries (Figure 2). A concrete curb was constructed around the perimeter of the system and the flow from the filter was directed to an existing roof drain.

The flotation unit had a rated capacity of 750 g.p.m.; therefore, it was necessary to reduce the flow to the filter to prevent overload. The use of a small adjustable weir plate in the effluent trough from the flotation unit permitted a small portion of the total flow to be diverted through a trough to a small stilling tank equipped with a standard V-notch weir. A clockwork operated water level recorder was installed in the stilling tank to continuously record flow levels. The flow from this tank was delivered to a second tank partitioned into two compartments so the waste could be pumped from one compartment to the trickling filter. The effluent from the filter was returned by gravity to the

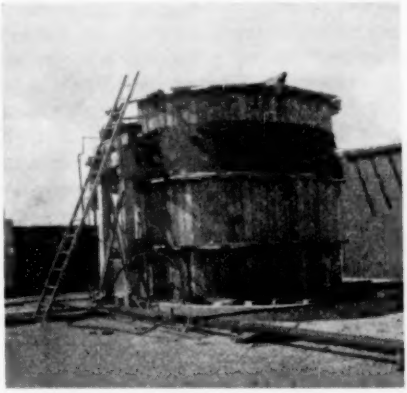

FIGURE 1.—Exterior of packinghouse waste trickling filter.

* Presented at the 1956 Annual Meeting, Iowa Sewage and Industrial Wastes Assn.; Clear Lake, Iowa; Sept. 12–14, 1956.

FIGURE 2.—Filter underdrains and curbing.

other compartment. This flow was discharged through an overflow pipe directly to the sewer. A pipe arrangement between the two compartments of the tank permitted controlled recirculation of the filter effluent. A water meter was installed in the piping to the trickling filter, and the flow to the filter was adjusted by means of a by-pass around the pump. Figure 3 shows a schematic diagram of the experimental system, including the treatment units ahead of the trickling filter.

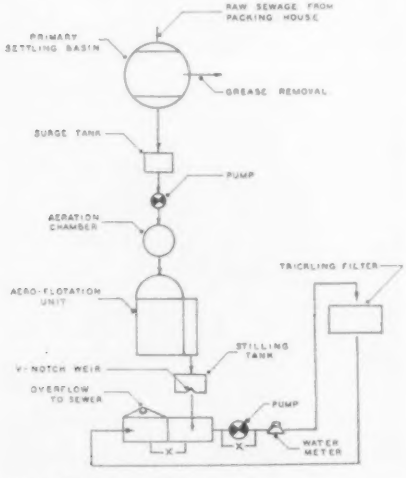

FIGURE 3.—Schematic diagram of packinghouse waste treatment facilities.

Startup and Operation

The filter was put into operation without particular regard to regulation of the flow. Initial difficulties encountered in achieving a reasonably uniform flow rate to the filter were caused by belt slippage on the pump pulleys. This problem was solved by the installation of a different pump with a more suitable drive arrangement. Flow to the filter then was adjusted to 50 g.p.m. by regulating the pump by-pass. Waste flow from the flotation unit to the filter was set at 34 g.p.m. and the remainder of the flow was made up of recirculated filter effluent. The recirculation rate was approximately 50 per cent and the rate of application was calculated to supply approximately 20 m.g.a.d. The 5-day B.O.D. loading was not determined.

After approximately 24 hr. of operation a film growth could be seen on the tile media. As the test continued it became evident that some factor was causing a recurring sloughing of the filter growth on a 7-day cycle.

In an effort to locate the cause of filter sloughing, the alum dosage to the flotation unit was reduced from 20 p.p.m. to 5 p.p.m., without success. The addition of food material during the weekend period when packinghouse operations were closed did not improve the filter condition. Also, maintaining a higher temperature in the flotation unit when the packinghouse was not operating had no effect. A 2-in. layer of red granite rock was placed on top of the tile media to help achieve better distribution of the wastes, but the sloughing continued.

As the weather became warmer, a heavier growth appeared on the granite rock. A clover-leaf shaped pattern could be seen on the surface of the rock where the growth obviously was

FIGURE 4.—Filter distributor and spray nozzles.

being scrubbed off by the force of the applied waste. In order to obtain better distribution on the filter, yet reduce the velocity of flow and still maintain the same volume, a series of six supplemental spray nozzles was arranged around the propeller distributor in a hexagonal pattern (Figure 4). Flow to the distributor was reduced and diverted into the nozzle system. This change resulted in better flow distribution and succeeded in reducing the amount of sloughing. Further investigation indicated that during weekend periods of low flow, mechanical loss of water from the system reduced the flow to the filter to a trickle. Arrangements were made to check the flow to the filter on a regular schedule and maintain a constant source of supply. This corrected the sloughing difficulties and the filter operated in a normal manner.

Sampling and Analyses

As soon as the filter appeared to be operating normally a program of sampling was begun and analytical data were obtained. During the first three days of the packinghouse operating week, 12-hr. composite samples were taken of the influent and effluent of the primary settling basin, the effluent of the flotation unit, and the effluent of the trickling filter. During the last two days, 12-hr. composite samples were taken only of the influent and effluent of the trickling filter. After thorough mixing, all trickling filter effluent samples were settled for 30-min. to duplicate the effect of a secondary clarifier which would normally follow such a filter installation.

The samples were analyzed for 5-day B.O.D., according to "Standard Methods" (2), oxygen consumed was determined by the chromate method (3) and grease removal and nitrogen content by the modified methods developed by the authors (4). Results of these analyses are shown in Tables I and II. The data derived from these analyses indicated that the trickling filter was accomplishing significant removals. Furthermore, the data showed that the reduction in the 5-day B.O.D. was greatest during the packinghouse non-operating hours. The average B.O.D. reduction for the 8 AM to 8 PM period was calculated to be 50 per cent, whereas for the 8 PM to 8 AM period the reduction was 61.2 per cent. This was to be expected since the B.O.D. value of the raw waste during the non-killing hours was less than one-half that during the killing hours.

Chemical oxygen consumed values tended to show a greater reduction during the operating period, but not to a significant degree. Reduction of the oxygen consumed value for the 8 AM to 8 PM period was 60.2 per cent and for the 8 PM to 8 AM period the reduction was 57.4 per cent.

Nitrogen content and grease removal were indicated to be quite good. An average reduction of 40.7 per cent of the nitrogen and 88.4 per cent of the grease was accomplished during the 8 AM to 8 PM period and 30.9 per cent of the nitrogen and 72.0 per cent of the grease during the 8 PM to 8 AM period.

The flow to the filter during a 24-hr. period averaged 72,000 gal., of which 45,000 gal. were raw waste. This represented a flow rate of 20.35 m.g.a.d. The B.O.D. loading rate averaged 4.97 lb. per cubic yard during the killing hours and 2.06 lb. per cubic yard during the non-killing hours. The average rate for the 24-hr. period was 3.53 lb. per cubic yard.

Summary and Conclusions

A trickling filter operating in conjunction with an air flotation unit will produce satisfactory results on packinghouse waste if proper care is given to assure a constant flow to the filter. Alum treatment of the waste in the flotation unit did not adversely affect the operation of the filter in concentrations up to 20 p.p.m. When the filter

TABLE I.—Operating Data for Settling Basin and Trickling Filter

Day	Period*	Filter Sample	B.O.D.		Oxygen Consumed		Nitrogen		Grease	
			(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)
Mon.	AM	Primary basin:								
		Influent	2,267	—	9,860	—	113	—	1,875	—
		Effluent	1,430	46.3	1,556	83.5	113	0	478	73.5
	AM	Flotation:								
		Influent	1,430	—	1,556	—	113	—	478	—
		Effluent	618	57.7	792	49.2	113	0	116	75.8
	AM	Filter:								
		Influent	618	—	792	—	113	—	116	—
		Effluent	269	56.5	342	56.8	49	56.7	31	73.3
	AM	Total reduction	—	90.0	—	96.5	—	85.8	—	98.5
	PM	Filter:								
		Influent	243	—	431	—	86	—	104	—
		Effluent	97	60.2	154	64.8	16	81.4	53	49.0
Tue.	AM	Primary basin:								
		Influent	1,643	—	3,450	—	122	—	606	—
		Effluent	717	55.8	1,587	54.0	90	26.2	316	48.0
	AM	Flotation:								
		Influent	717	—	1,587	—	90	—	316	—
		Effluent	400	44.2	1,001	36.9	81	10.0	146	53.8
	AM	Filter:								
		Influent	400	—	1,001	—	81	—	146	—
		Effluent	204	49.2	306	69.6	60	26.0	29	80.2
		Total reduction	—	87.5	—	91.5	—	85.4	—	95.2
	PM	Filter:								
		Influent	171	—	281	—	22	—	23	—
		Effluent	79	53.7	84	70.3	18	18.2	0	100.0
Wed.	AM	Primary basin:								
		Influent	1,556	—	5,936	—	113	—	2,317	—
		Effluent	871	44.1	1,335	77.7	113	0	526	77.5
		Flotation:								
		Influent	871	—	1,335	—	113	—	526	—
		Effluent	388	55.5	627	53.1	113	0	155	70.5
		Filter:								
		Influent	388	—	627	—	113	—	155	—
		Effluent	148	62.0	308	51.3	49	56.6	0	100.0
		Total reduction	—	90.5	—	95.0	—	56.6	—	100.0
	PM	Filter:								
		Influent	156	—	303	—	42	—	0	—
		Effluent	40	74.2	146	51.8	34	19.0	0	—

* Periods, 8 AM to 8 PM and 8 PM to 8 AM.

TABLE II.—Trickling Filter Operating Data

Day	Period*	Filter Sample	B.O.D.		Oxygen Consumed		Nitrogen		Grease	
			(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)
Thur.	AM	Influent	304	—	—	—	70	—	0	—
		Effluent	192	37.0	622	—	51	27.2	0	—
	PM	Influent	150	—	702	—	51	—	0	—
		Effluent	82	45.3	422	40.0	40	18.0	0	—
Fri.	AM	Influent	167	—	1,199	—	65	—	17	—
		Effluent	93	44.3	420	65.0	41	36.9	0	100.0
	PM	Influent	62	—	360	—	22	—	25	—
		Effluent	17	72.5	122	60.2	18	18.2	15	38.9

* Periods, 8 AM to 8 PM and 8 PM to 8 AM.

was operated as a high-rate unit with a flow rate of 20 m.g.a.d. and a recirculation rate of 50 per cent, a B.O.D. reduction of 50 per cent was obtained, even with B.O.D. loadings as high as 4.97 lb. per cubic yard. It would be reasonable to assume that if the B.O.D. loadings were reduced to 2.0 to 2.5 lb. per cubic yard, removals of 60 to 65 per cent could be expected. This is substantiated by the fact that during the non-killing hours, B.O.D. loadings of 2.06 lb. per cubic yard resulted in an average B.O.D. reduction of 61.2 per cent.

The average reductions in B.O.D., oxygen consumed, grease, and nitrogen accomplished by all the units employed in this test compare favorably with the reductions given for more conventional combinations of secondary treatment units.

Acknowledgment

The authors express appreciation for the valuable contributions of time and advice given by M. L. Wickersheim, Superintendent of the Estherville, Iowa, municipal sewage treatment plant.

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TRICKLING FILTER STUDIES IN TREATING PULP AND PAPER MILL WASTES *

By James E. Lebo and John W. Hassler

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The studies herein recorded are an outgrowth of management's desire to search out a satisfactory means for more complete treatment of the pulp and paper mill wastes from the West Virginia Pulp and Paper Company's mill at Tyrone, Pa. This paper deals primarily with laboratory and pilot-plant studies of the trickling filter for treating pulp and paper mill wastes. Also included are data relative to the Tyrone mill processes, waste characteristics, present treatment facilities, and other pertinent information.

The first step involved a literature search on the treatment of industrial wastes with particular reference to pulp and paper mill effluents. This was followed by a survey of the local wastes to establish pollutional properties and the volumes involved.

Process Flow Diagram

The Tyrone mill is an integrated mill; that is, the process includes the separation of pulp fibers from wood and conversion to the end product—paper. The chemicals used in the modified sulfate cooking (digestion) stage are recovered from the spent liquors for re-use in the process.

Figure 1 shows the principal steps in the pulp, paper, and chemical recovery processes. The majority of the liquid wastes requiring treatment come from the screen room and bleachery of the pulp mill, the evaporator and lime kiln of the chemical recovery, and the paper machine.

Present Treatment Facilities

At present, all liquid wastes are discharged to a commen sewer and flow to a mechanically-cleaned settling basin. With present production, the total mill flow averages 6 m.g.d.; the settling basin provides a retention time of 2 hr.

Properties of the Waste Effluents

The approximate B.O.D. values of those effluents contributing the major portion of the total B.O.D. load are shown in Table I. It should be noted that the B.O.D. of the screen room and paper mill wastes is mainly due to filterable matter (suspended and settleable), whereas the B.O.D. of the bleachery and evaporator condensate

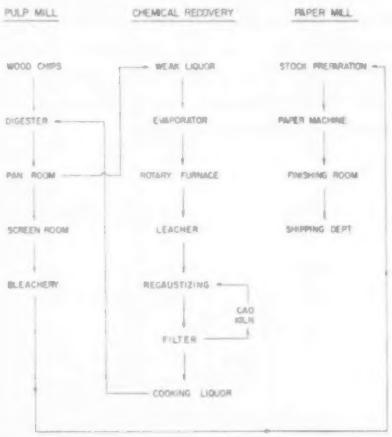

FIGURE 1.—Principal steps in pulp and paper making and chemical recovery.

* Presented at 1956 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 29–31, 1956.

TABLE I.—Approximate 5-Day B.O.D. Values of Various Tyrone Mill Effluents

Effluent	Concentration (p.p.m.)			Loading (lb./day)		
	Filterable	Dissolved	Total	Filterable	Dissolved	Total
Screen room	243	97	340	300	150	450
Bleachery	20	115	135	500	2,750	3,250
Evap. condensate	57	438	495	220	1,330	1,550
Paper mill[1]	130	45	175	450	300	750
Miscellaneous	—	—	50	—	—	800

[1] Does not include white water from save-alls.

wastes is, for the most part, due to matter in aqueous solution. The same table gives the loading attributable to each effluent. It will be observed that wastes containing dissolved B.O.D. contribute the major portion of the total B.O.D. loading.

This brought a realization that appreciable B.O.D. reduction would require removal of the dissolved compounds affecting B.O.D. This, in turn, led to investigations of biological treatment methods.

Laboratory Treatment by Activated Sludge

The initial studies of biological treatment utilized the activated sludge principle. The equipment is shown in Figure 2. Data for treatment of the combined mill wastes (settling basin effluent) in the activated sludge pots are summarized in Figure 3.

The conditions were as follows:

1. Acclimated sewage sludge seed.
2. Three-hour aeration period.
3. Mixed liquor solids, range 2 to 4 g. per liter, average 3 g. per liter.
4. pH range, 7 to 10.
5. Nutrient, 1 p.p.m. nitrogen (as ammonium sulfate).

Additional studies made on separate wastes and various composites revealed that activated sludge treatment effectively removed the B.O.D. in all the various wastes or combinations, provided they were properly preconditioned.

The success of the activated sludge treatment led to consideration of other biological processes—and in particular to studies of the trickling filter.

Laboratory Trickling Filter Treatment

The laboratory-size trickling filter as used in the initial step is illustrated in Figure 4.

Applying settling basin effluent wastes, this unit was operated continuously for a period of approximately three months. Representative data from this work are shown in Figure 5. The conditions during this laboratory

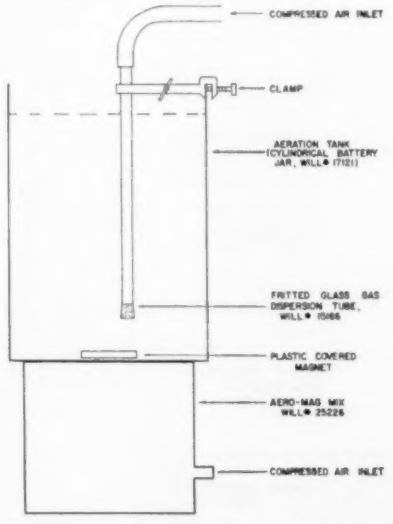
COMPRESSED AIR INLET
CLAMP
AERATION TANK (CYLINDRICAL BATTERY JAR, WILL● 17121)
FRITTED GLASS GAS DISPERSION TUBE, WILL● 15466
PLASTIC COVERED MAGNET
AERO-MAG MIX WILL● 25226
COMPRESSED AIR INLET

FIGURE 2.—Aeration and stirring apparatus used in the activated sludge studies.

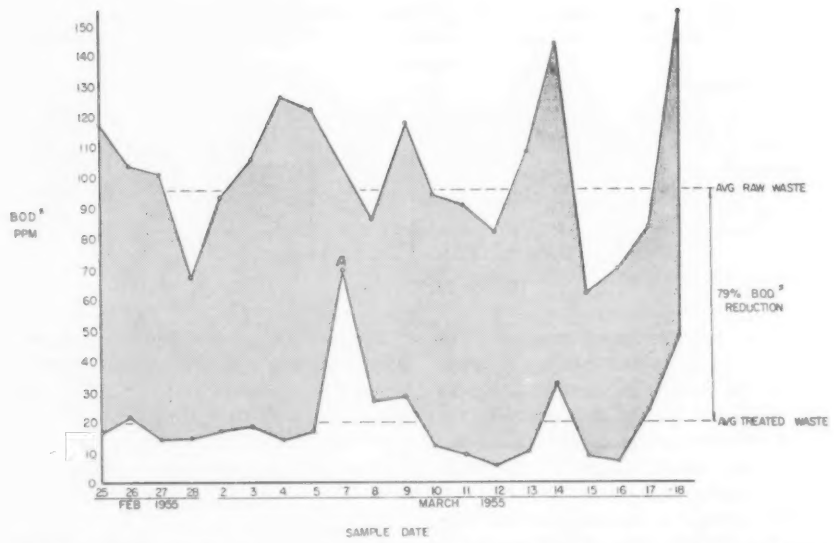

FIGURE 3.—Data on laboratory activated sludge treatment of settling basin effluent.

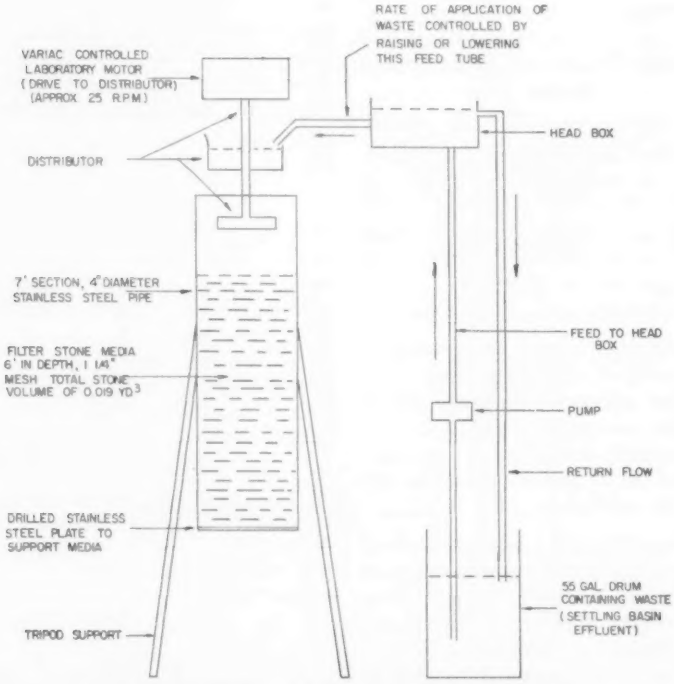
RATE OF APPLICATION OF WASTE CONTROLLED BY RAISING OR LOWERING THIS FEED TUBE
VARIAC CONTROLLED LABORATORY MOTOR (DRIVE TO DISTRIBUTOR) (APPROX 25 R.P.M.)
HEAD BOX
DISTRIBUTOR
7' SECTION, 4" DIAMETER STAINLESS STEEL PIPE
FILTER STONE MEDIA 6' IN DEPTH, 1 1/4" MESH TOTAL STONE VOLUME OF 0.019 YD3
FEED TO HEAD BOX
PUMP
RETURN FLOW
DRILLED STAINLESS STEEL PLATE TO SUPPORT MEDIA
55 GAL. DRUM CONTAINING WASTE (SETTLING BASIN EFFLUENT)
TRIPOD SUPPORT

FIGURE 4.—Laboratory trickling filter and flow pattern.

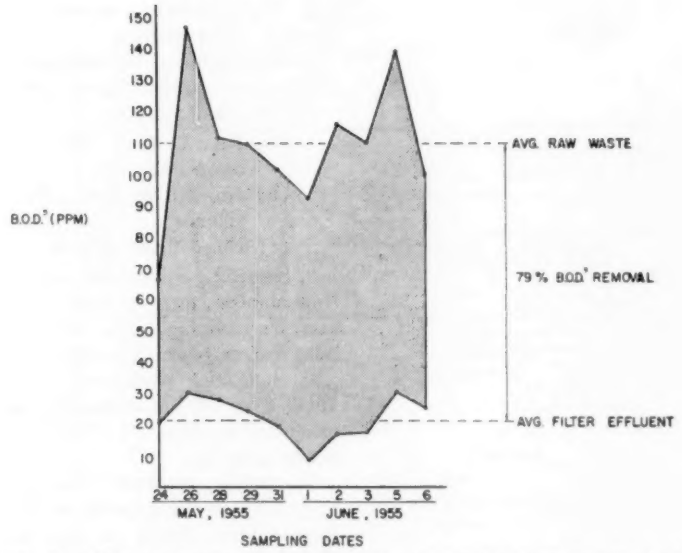

FIGURE 5.—Data on laboratory trickling filter treatment of settling basin effluent.

study were as follows:

1. Hydraulic loading, 20 m.g.a.d.
2. Recirculation ratio, 3; that is, four passes through the filter.
3. Waste temperature, range of 25° to 30° C.
4. Nutrient, 1 p.p.m. nitrogen (as ammonium sulfate).
5. pH range, 6.8 to 9.0.

The favorable aspects of the data resulted in approval by management of the erection of a pilot-scale filter.

Design of Pilot Filter Unit

The pilot unit included two filters with flexible control to facilitate the use of varying flow patterns and hydraulic loadings. The size of the filters was governed by (a) information from the literature, which indicated that flows of 5 to 20 g.p.m. through a pilot unit were adequate to supply suitable data for plant-size design; and (b) the laboratory studies, which suggested hydraulic loadings in the 20- to 50-m.g.a.d. range. This placed the minimum size of the filter at 5 ft. in diameter. The engineering facilities of the Tyrone mill designed the pilot unit and many

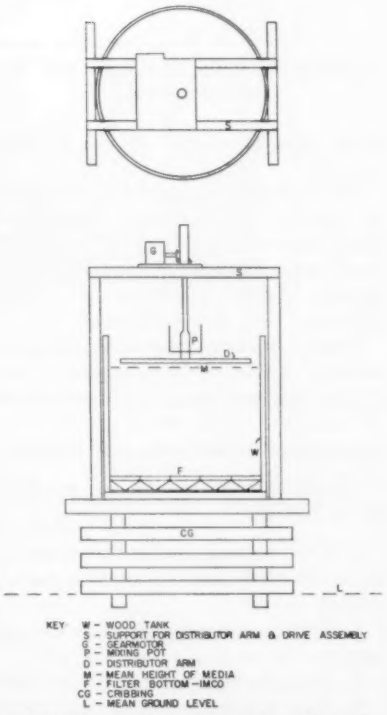

FIGURE 6.—Top view and section of trickling filter.

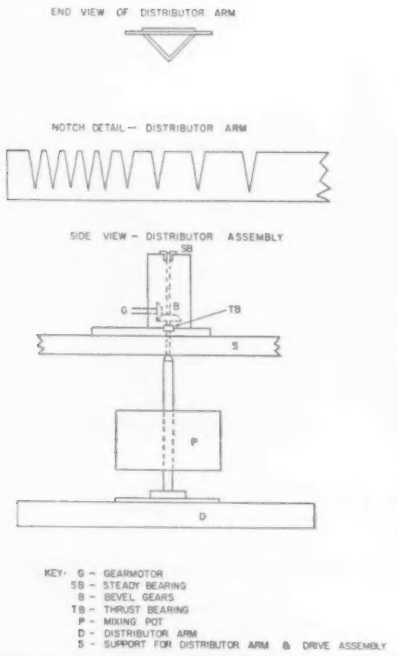

FIGURE 7.—Filter distributor and drive assembly details.

parts were fabricated in the shops at the mill.

The unit was comprised of two filters of similar construction (Figure 6). Each filter was a 6-ft. O.D. bottomless wood tank elevated on cribbing, containing a 6-ft. depth of No. 4 size limestone (2¾- to 4½-in. mesh).

Figure 7 shows the distributor assembly, which is top-supported and driven by a gear motor and bevel gears.

Operational Provisions and Practices

Operational provisions and practices are as follows:

1. Flow pattern:—The filters are operated in series, with provision for recycling.
2. Waste conveyance:—Centrifugal pumps.
3. Flow measurement:—Flowrators.
4. Flow control:—Valve adjustment (manual).
5. Temperature measurement:—Weston thermometers.
6. Nutrient and/or chemical feed:—Sigmamotor proportioning pumps.
7. Sampling points:—
   (a) No. 1 filter feed (settling basin effluent).
   (b) No. 2 filter feed (No. 1 filter effluent).
   (c) No. 2 filter effluent.
8. Sampling equipment:—Originally, Sigmamotor pump; later, automatic sampler utilizing timer-controlled solenoid valves (June 15, 1956).
9. Sampling period:—To June 15, 1956, 8 to 10 AM composite samples; on and after June 15, 1956, 24-hr. composite samples.
10. Solids removal:—No provision originally; settling tanks to receive effluents from No. 1 as well as No. 2 filter after June 9, 1956.

Operational and Analytical Data of Filter Pilot Unit

When placed in operation on November 14, 1955, the filter was seeded with activated sludge from the Altoona (Pa.) sewage treatment plant. Analytical measurements of the effect on the applied wastes commenced on November 30, 1955.

For the period covered by this paper, the flow pattern was series operation with no recirculation (that is, one pass through each filter); excepting brief periods during December 1955 and January 1956, when a portion of No. 2 filter effluent was returned to No. 1 filter.

The data on nutrient feed, pH, temperature, hydraulic loading, and B.O.D. reduction covering the months of December 1955 through June 1956 are shown in Figures 8, 9 and 10. Figure 8 shows the data for the period December 1955 through February 1956. During this initial period, which covered the winter season, the nutrient feed consisted of 2 p.p.m. nitrogen up to February 15, when it was discon-

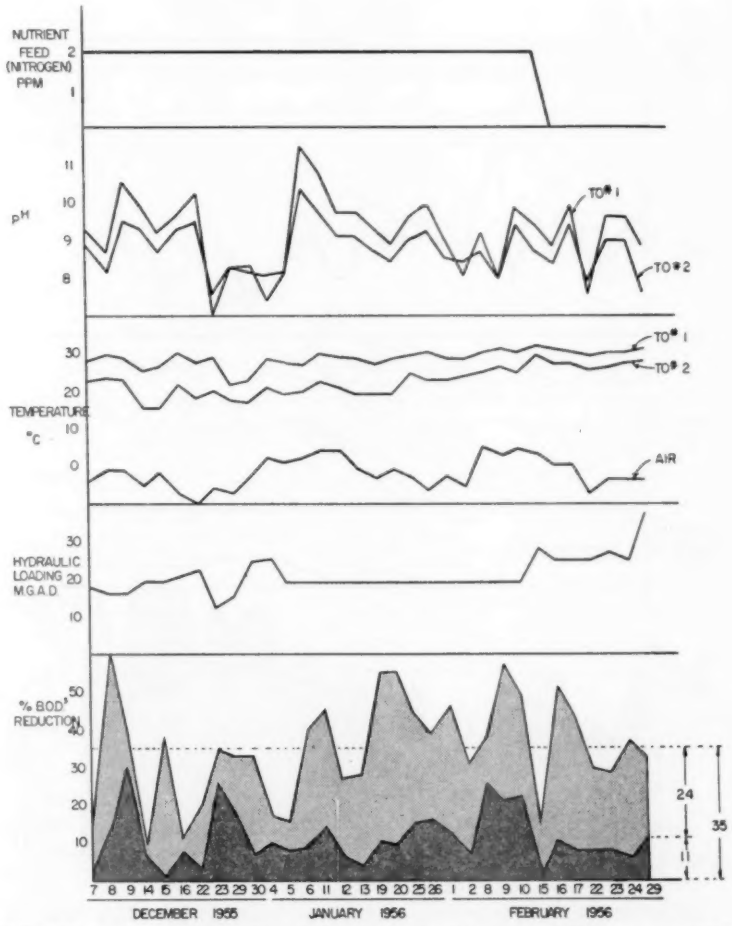

FIGURE 8.—Data for trickling filter pilot unit, December 1955–February 1956.*

tinued. The pH of the influent to the No. 1 filter ranged from 7.0 to 11.5, averaging around 9.2. Passage of the waste through the No. 1 filter effected a change in the pH; in general, the pH going to the second filter during this period was somewhat lower.

During this period the temperature of the waste applied to the No. 1 filter ranged from 21° to 32° C. Passage through the No. 1 filter cooled the wastes somewhat, resulting in a lower temperature of the influent to the No. 2 filter. The air temperature ranged from − 10° to 5° C. The hydraulic loading ranged from 12.5 to 37 m.g.a.d., averaging 21 m.g.a.d.

During this same period the B.O.D. reduction ranged from a low of 3 per cent to a maximum of 47 per cent in the No. 1 filter, whereas in the No. 2 filter it ranged from 1 to 30 per cent. The over-all reduction ranged from 9 to 61 per cent, with an average of 35 per cent.

*B.O.D. reduction through No. 1 filter shown by light shaded area and that through No. 2 filter by dark area.

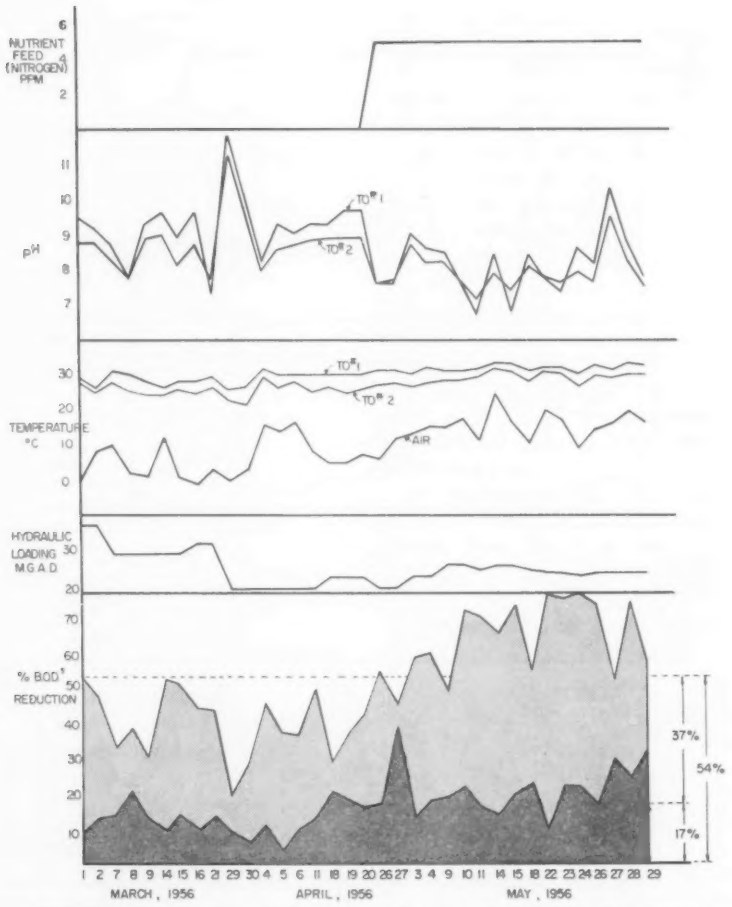

FIGURE 9.—Data for trickling filter pilot unit, March 1956–May 1956.*

Figure 9 covers the period of March, April, and May, 1956. It will be noted that the nutrient feed, which had been discontinued on February 15, was resumed on April 20, but with an increased dosage of 5 p.p.m. Also, there was a trend to a decrease in pH and, of course, a gradual general increase in air temperature. All of these factors contributed in some measure to the definite improvement in B.O.D. removal effected by the pilot unit, particularly noticeable during May.

* B.O.D. reduction through No. 1 filter shown by light shaded area and that through No. 2 filter by dark area.

Figure 10 shows the data for June 1956. The consistency relative to B.O.D. reduction may be due in part to the fact that during the second half of this month the sampling was done on a 24-hr. basis rather than by short-term composite samples taken only during the day. Also, it will be noted that the pH shows a further decline and the hydraulic loading is increased.

Data Summary

Regardless of how expressed, the B.O.D. removed for the three-months period, December 1955 through Febru-

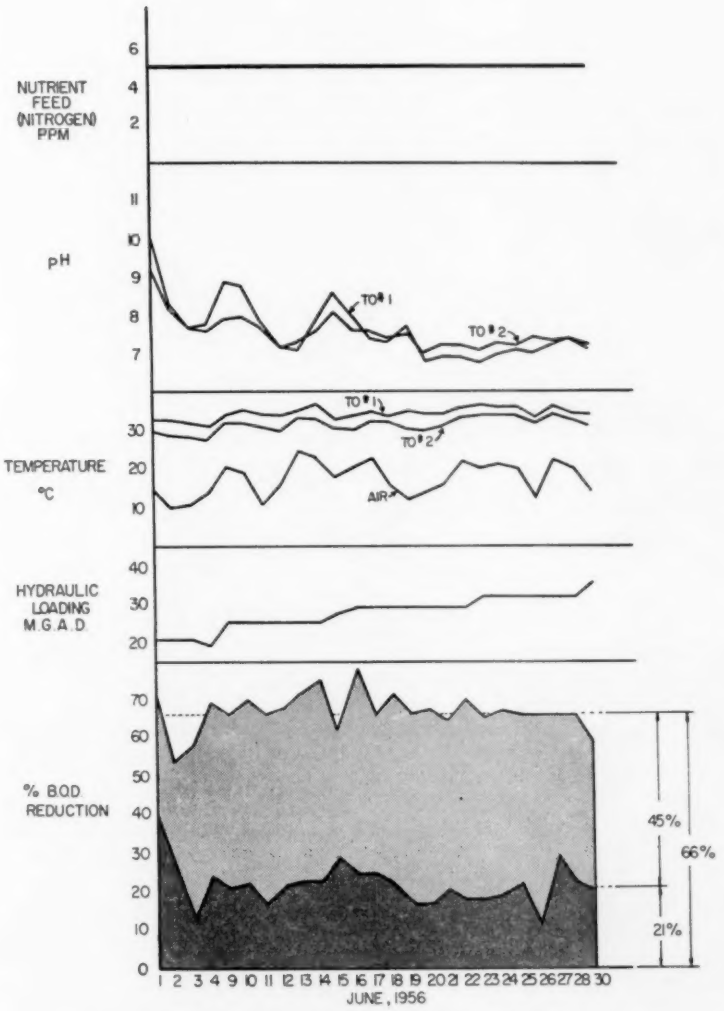

FIGURE 10.—Data for trickling filter pilot unit, June 1956.*

ary 1956, was relatively small. Moreover, the results varied from one day to the next. However, about the middle of January 1956 general improvements seemed to be effected. A large part of this improvement was due to steps that were taken to compensate for the residual chlorine present in the wastes applied to the first filter. It is of interest to note that the B.O.D. concentration of wastes applied to the unit for this period averaged 120 p.p.m., whereas the residual B.O.D. in the effluent discharged to the stream averaged approximately 80 p.p.m. The following is a summary of these data:

* B.O.D. reduction through No. 1 filter shown by light shaded area and that through No. 2 filter by dark area.

1. B.O.D. applied (p.p.m.):—No. 1 filter, range 58 to 174 p.p.m., average 121 p.p.m.; No. 2 filter, range 40 to 131 p.p.m., average 91 p.p.m.

2. B.O.D. removed:—No. 1 filter, range 3 to 47 per cent, average 24 per cent; No. 2 filter, range 1 to 30, average 11 per cent; over-all, range 9 to 61 per cent, average 35 per cent.

3. B.O.D. applied (lb. per cu. yd. per day):—No. 1 filter, range 0.77 to 4.74, average 2.23; No. 2 filter, range 0.66 to 4.22, average 1.70.

4. B.O.D. removed (lb. per cu. yd. per day):—No. 1 filter, range 0.05 to 1.32, average 0.53; No. 2 filter, range 0.02 to 1.00, average 0.24.

In March, April, and May 1956 there was a gradual and definite improvement in B.O.D. removal effected by the pilot unit. This improved efficiency resulted in lower B.O.D. residuals in the pilot unit effluents. For this period these effluents contained an average of approximately 60 p.p.m. B.O.D. as compared to the 80 p.p.m. in the previous 3-month period. The following is a summary of these data:

1. B.O.D. applied (p.p.m.):—No. 1 filter, range 75 to 208 p.p.m., average 128 p.p.m.; No. 2 filter, range 45 to 159 p.p.m., average 81 p.p.m.

2. B.O.D. removed:—No. 1 filter, range 3 to 67 per cent, average 37 per cent; No. 2 filter, range 4 to 39 per cent, average 17 per cent; over-all, range 20 to 78 per cent, average 54 per cent.

3. B.O.D. applied (lb. per cu. yd. per day):—No. 1 filter, range 1.26 to 4.37, average 2.75; No. 2 filter, range 0.97 to 3.34, average 1.75.

4. B.O.D. removed (lb. per cu. yd. per day):—No. 1 filter, range 0.10 to 2.39, average 1.00; No. 2 filter, range 0.08 to 0.87, average 0.46.

In June 1956 the removals effected by the pilot unit were very consistent. Moreover, on and after June 15 the daily sampling covered a 24-hr. period; hence, the improvement in consistency is real. Furthermore, it is well to point out that this consistency extended to the B.O.D. residual in the effluent delivered to the stream. During June the pilot unit delivered effluents containing a B.O.D. concentration of less than 40 p.p.m. on the average. A summary of these data is as follows:

1. B.O.D. applied (p.p.m.):—No. 1 filter, range 87 to 147 p.p.m., average 116 p.p.m.; No. 2 filter, range 52 to 95 p.p.m., average 64 p.p.m.

2. B.O.D. removed (%):—No. 1 filter, range 27 to 54, average 45; No. 2 filter, range 13 to 40, average 21; over-all, range 54 to 78, average 66.

3. B.O.D. applied (lb. per cu. yd. per day):—No. 1 filter, range 1.92 to 3.84, average 2.81; No. 2 filter, range 0.91 to 1.99, average 1.54.

4. B.O.D. removed (lb. per cu. yd. per day):—No. 1 filter, range 0.64 to 1.88, average 1.28; No. 2 filter, range 0.25 to 0.86, average 0.60.

Figure 11 consolidates significant data to illustrate trends over the entire period of December 1955 through June 1956. It will be noted that the B.O.D. removal by the first filter was greater than by the second. Also, that there was an appreciable increase in the B.O.D. reduction during May and June. This could be due to several factors. First, the air temperature showed a definite increase during this period. But in addition there are other factors to be considered; for example, the nitrogen feed was 5 p.p.m. during this latter period and, moreover, there was a general tendency for a lower pH in the applied wastes.

It also will be observed that the trend of B.O.D. removal in pounds per cubic yard per day follows closely that of the B.O.D. reduction expressed as a percentage.

Conclusions

Laboratory studies indicated that equally satisfactory B.O.D. reductions

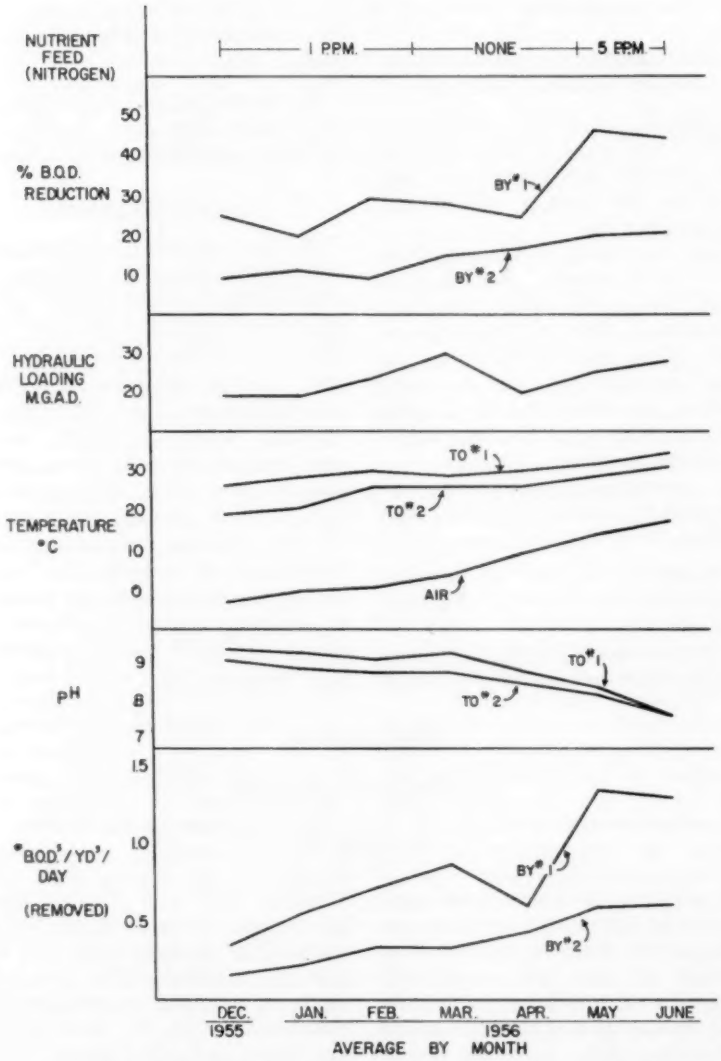

FIGURE 11.—Monthly average data for trickling filter pilot unit.

could be accomplished by trickling filter as by activated sludge treatment.

The initial performance of the pilot trickling filter unit was not very consistent. In part, this may have been due to low air temperatures because of the winter season, but much of the inconsistency was due to irregular and often high chlorine residual in the applied wastes. Certainly steps taken to correct for chlorine residual resulted in an appreciable improvement in B.O.D. removal efficiency.

As the studies progressed to spring, still greater efficiency was realized. The known factors involved in this were as follows:

1. Higher temperature, both air and wastes.
2. More satisfactory pH conditions.
3. Adequate nutrient (nitrogen).

In general, the B.O.D. removal was greater in the No. 1 filter than in No. 2 filter, whether expressed as percentage or on the basis of pounds per cubic yard per day.

Wastes containing substances harmful to bio-organisms (for example, chlorine, free alkali, sulfides, etc.) have a detrimental effect on the B.O.D. removal. When such contaminants are present intermittently and for short periods of time (shock loads), the filter rapidly recovers after the cessation of the adverse condition.

The occurrence of such adverse conditions can be minimized by the collective effect of the following:

1. Improved control of separate wastes delivered from individual departments.
2. Contemplated changes in the primary treatment system to provide an averaging out of variation in pH and the elimination of chlorine residuals, sulfides, etc.

No mechanical difficulties have been experienced thus far. In this, there has been no evidence of plugging.

Acknowledgments

The authors wish to acknowledge the full support, splendid cooperation, and sincere interest of the Tyrone mill personnel in general, and the following in particular: J. Lynne Ferner, mill manager; Henry Laughlin, assistant research director; Floyd Campbell, chief chemist; Robert Roseberry, assistant chief chemist; John Stephens, research chemist; Mrs. Grace Holmes, chemist; Robert Steck, sanitary engineer; Miss M. Jane Bradin, chemist; and Miss Ruth Caldwell, technician.

The distributor assembly design was supplied through the courtesy of John Vogler and A. B. Cherry of the American Cyanamid Co.

DISCUSSION

By Francis B. Milligan

Chief, Industrial Wastes Section, Pennsylvania State Department of Health. Harrisburg, Pa.

The studies and development work described in the preceding paper sum up the present status of trickling filter treatment of pu' and paper mill wastes. An effort is being made to establish reasonable and practical means for treating this industrial waste to a degree sufficiently high to meet the minimum requirements of the Pennsylvania Sanitary Water Board for so-called "complete" or high-degree treatment. Adequate treatment of pulp and paper mill wastes has been a long time coming and, of course, it is not here yet, but certainly it is in sight.

Careful and continuing studies at the Tyrone (Pa.) mill of the West Virginia Pulp and Paper Company on the use of a trickling filter for wastes from an integrated mill, which uses the modified sulfate process for pulp manufacture or preparation in combination with the manufacture of fine tablet and other paper, are covered very clearly in the presentation by Hassler and Lebo.

The results obtained at the Tyrone mill are in general paralleled by the experimental work on treatment of wastes from the integrated mill of the New York and Pennsylvania Company at Johnsonburg, Pa., using a biological filter pilot plant.

The initial series of tests of the experimental biological filter at the

Johsonburg mill was conducted by the National Council for Stream Improvement of the Pulp and Paper Industries, in cooperation with the New York and Pennsylvania Company. Copies of the data obtained were supplied to the Pennsylvania Sanitary Water Board.

A single filter, 6 ft. in diameter by 6 ft. in depth, was used. The filter medium was broken limestone, supposedly between 1 and 3 in. in diameter. However, although the specifications required that at least 50 per cent of the stone be between 2 and 3 in. in diameter with not more than 3 per cent less than 1 in., it was later found, by means of a careful gradation test, that actual sizes ranged from 2 in. to fine sand; 60 per cent of the media passed a 1½-in. ring, and less than 3 per cent was retained on a 2-in. ring.

After an initial start-up period, using raw sewage for seeding, the filter was placed in regular operation in June 1953. Various dosing rates were tried, and a rate of 20 m.g.a.d. without recirculation was selected and used throughout all subsequent tests. Nutrients were added regularly during all tests. The nitrogen dose was 8 p.p.m. (probably as ammonium sulfate) and the phosphorus was 3 p.p.m. (as phosphorus pentoxide). The pH of the filter influent ranged between 6.2 and 7.4.

Ponding occurred in October and later the filter clogged entirely, so that operation of the pilot plant was discontinued near the end of December 1953.

When the filter was examined carefully it was found that clogging was caused by small granules of limestone, which entirely filled the voids between the larger stones in the filter medium, and not by organic material. Some slimes, largely fungi, and some paper fiber were found just below the surface of the filter, and apparently had collected after the granular material had been washed down into the filter and compacted sufficiently to cause serious ponding.

In the spring of 1954, at the request of the Pennsylvania State Department of Health, after the original filter had been torn down and examined, the New York and Pennsylvania Company reconstructed the filter and operated it in cooperation with the department of health; the company staff did most of the field work in addition to checking analyses. Duplicate tests also were done concurrently in the central laboratory of the health department. All data were made available by the company and the health department.

The filter was operated from June until December 1954 at the 20 m.g.a.d. rate without recirculation, and nutrients were added at the same rate as in the previous tests. The pH ranged from 6.2 to 7.4. No ponding was experienced during the second period of operation. Limestone was again used as the filter medium. This time it was placed carefully to prevent abrasion of the stone and the deposition of fines in the filter. About one-third of the stone was retained on a 1½-in. screen, and two-thirds passed the screen; the smallest stone size was about 1 in.

The B.O.D. of the raw waste averaged 125 p.p.m., and did not vary greatly. The B.O.D. reductions varied from 31 to 48 per cent, and averaged 40 per cent. The B.O.D. loading averaged 2.08 lb. of B.O.D. per cubic yard of filter media, and did not vary widely except after spills or other abnormal occurrences in the mill.

The operation of the Johnsonburg pilot filter was not continued into 1955 because of a lack of personnel. This prevented a test of the effect of an increase from 20 m.g.a.d. to 30 m.g.a.d. in the hydraulic dosing rate on the filter. It seems probable that improved results would have followed, to judge from the experience at Tyrone, Pa.

During the Tyrone studies there

were two experimental filters operated in series, each equal in size to that of the single filter at Johnsonburg; each filter was 6 ft. in diameter by 6 ft. in depth. The filter stone varied from 2¾ to 4½ in. in size and therefore was appreciably larger than the Johnsonburg stone. Recirculation was not used. The rate of dosage was increased from an average of 21 m.g.a.d. for December 1955 through February 1956 to an average of 27 m.g.a.d. in June 1956; therefore, it was somewhat greater than the rate on the filter at Johnsonburg.

The B.O.D. loading on the entire pilot plant at Tyrone (two filters) increased from an initial rate of 1.12 lb. of B.O.D. per cubic yard of total filter stone to an average of 1.4 lb. per cubic yard from March through June 1956, as compared with 2.08 lb. per cubic yard at Johnsonburg.

The nutrient was nitrogen as ammonium sulfate, which during the June 1956 operating period was added at the rate of 5 p.p.m., but no phosphorus was added. The pH of the influent varied from 11.5 to 7, approaching the latter value more closely during the June operation. The nutrient feed and pH values, and the B.O.D. value of 122 p.p.m. in the wastes after primary treatment, closely approximate the characteristics at Johnsonburg. The use of the secondary filter, however, markedly increased the overall effectiveness of the units, so that the total B.O.D. reduction in the third period averaged better than 65 per cent.

It is noteworthy that the average percentage reductions at Tyrone, after seeding and during the period from March to May 1956, showed an average percentage B.O.D. reduction through the primary trickling filter of 37 per cent, and in June 1956 the average reduction was 45 per cent. These values parallel quite closely the results obtained with the single filter at Johnsonburg.

FELLOWSHIPS AVAILABLE

Rutgers University—Research fellowships leading to the M.S. and Ph.D. degrees in the fields of water supply, sewage and industrial waste treatment, stream pollution, and air pollution are available to professional engineers and scientists. The stipend ranges from $1,800 to $2,400, plus 12 credit hours per semester of free tuition. Appointments are on a 12-month basis with one month of vacation. Available July and September, 1957.

Applications may be obtained from Dr. H. Heukelekian, Chairman, Department of Sanitation, Rutgers University, New Brunswick, N. J.

New York University—Graduate assistantship in sanitary engineering or sanitary science. Remuneration is $1,400 per year plus tuition fees, half-time service required; available September, 1957.

For information write to Professor James Michalos, Chairman, Department of Civil Engineering, New York University, University Heights, New York 53, N. Y.

University of North Carolina—Graduate assistantships in sanitary engineering and sanitary science leading to the M.S. degree. Minimum stipend, $1,500 for 9 months, half-time teaching or research; available 1957–58 academic year.

Information may be obtained from the Department of Sanitary Engineering, School of Public Health, University of North Carolina, Box 899, Chapel Hill, N. C.

Tau Beta Pi Fellowships—Fellowships of $1,500 per year for graduate study in engineering during the 1957–58 academic year are available to all Tau Beta Pi members. For additional information write to Paul H. Robbins, Director of Fellowships, 2029 K St., N. W., Washington 6, D. C.

DISCHARGE OF INDUSTRIAL WASTES INTO MUNICIPAL SEWER SYSTEMS— A PANEL DISCUSSION *

I. INTRODUCTION

By Frederick W. Crane

General Manager, Buffalo Sewer Authority, Buffalo, N. Y.

The earliest interests regarding impurities carried by used waters were of contamination by domestic sewage and exposure to infectious disease. As sewer systems became more common and more streams received sewage wastes, the problem of satisfying the oxygen requirements of used water gave impetus to the development of sewage treatment plants.

However, the problem of developing processes and designing plants to aid nature in the normal process of biologically destroying organic wastes is a simple one in contrast to the complexity of the problems created by the wastes produced by the many industrial processes that require the use of water.

This panel was selected to discuss whether or not industrial wastes should be accepted in a municipal sewer system; if accepted, what limitations or restrictions should be placed on such acceptance, and what if any special charges should be imposed.

There is on old saying that "a fisherman telling the truth is never very interesting." Therefore, for the purpose of encouraging discussion, one or two of the panel members have been asked to express a bias with which they may not be wholly in agreement.

The panel members are experts. Each in his daily work deals with some phase of industrial wastes treatment or disposal.

II. SOME GENERAL PRINCIPLES

By Donald B. Stevens

Associate Chemical Engineer, New York State Department of Health, Albany, N. Y.

It would help in the discussion of this topic to consider first the principle on which a municipal sewer system is conceived and constructed. This principle is to bring together all the waste waters of a community and accord them sufficient treatment so that the final effluent will not contravene the standards of purity and quality established for the receiving waters. This is based on the idea that it is cheaper to solve the problem as one unit instead of several, and many times it is the only way that corrections can be made in concentrated areas of population. This has given rise to the idea that it would be a cheap way to dispose of industrial wastes. If the wastes will be lost in the total flow to a plant, it undoubtedly would be a cheap and practical method.

However, on this principle the inclu-

* Presented at the Operators' Breakfast, 1956 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Buffalo, N. Y.; May 28–29, 1956.

sion of some items may run the costs up way out of proportion to the benefits derived. An extreme example would be to build a sewage treatment plant of sufficient size to handle all the storm water of a community. Certainly the benefits would be only a small fraction of the costs. Another example would be the extension of a sewer line a mile or more through vacant property to serve a single house.

With these ideas in mind, let us look at the liquid wastes from an industry and decide whether there would be any advantage to discharging them to a municipal sewer system. This sewer system is assumed to be the sanitary sewer system.

One of the largest sources of waste water from many industries is that of water used in indirect cooling. If this water is unpolluted, as it should be, it will not benefit from passage through the sewage treatment plant and in many cases will overload it hydraulically. Therefore, this water should be kept separate from all other wastes and discharged directly to surface waters or separate storm water drains. The only exception to this should be when the temperature of the water is excessive. In that case some pretreatment to reduce the temperature would be necessary.

Nearly the same comments can be made with reference to storm waters. Here, care should be taken in the matter of storage around the yards to see that the rain does not pick up too much material between the point where it reaches the ground and where it leaves the property.

There is little question but that sanitary wastes should be discharged to the municipal sewer. In cases where there is a rest room on the property at a remote point from the sewer, it would be satisfactory to install a private sewage disposal system providing the installation has the approval of the local health department.

As to the actual polluted wastes from the plant operations, individual appraisals must be made. On the surface it would not seem desirable to discharge a waste with a high dissolved B.O.D. to a primary treatment plant. However, if the strengths and quantities are such that the dilution factor is sufficient so that stream standards are not violated by the plant effluent, it would be permissible. The same principle would apply to acidic or caustic wastes. In these cases it might be necessary to require holding tanks with regulated discharges rather then promiscuous dumping.

However, with a waste containing a toxic material like copper, dilution would not play a part; the copper would concentrate in the sewage treatment plant and interfere with sludge digestion. Therefore, materials of this type should be excluded from the sewer system.

Materials like gasoline or other flammable materials should be excluded from the sewers, due to the possibility of explosions in the sewers or fires in the treatment plant. There are instances on record where this has occurred. Carrying this idea farther would be the exclusion of volatile materials which would create hazardous working conditions at the treatment plant.

This line of reasoning leads to the recommendation that each community having a sewer system should enact a sewer ordinance. The model sewer ordinance developed by the Federation of Sewage and Industrial Wastes Associations is good, but each community should use it as the basis for its own ordinance and develop one specifically for its own use rather than adopting the model ordinance blindly.

Whose responsibility is it to state whether an industrial waste is acceptable to a municipal sewer system or not? This duty rests squarely on the shoulders of the owner of the sewer

system and constitutes another argument for a sewer ordinance.

Where does the state enter this picture? The state comes in in two places. One is the quality of the receiving waters. If the municipality accepts the industrial waste, it should treat that waste to such an extent that the established standards of the receiving waters are not contravened. The other is in the operation of the sewage treatment plant itself. In both of these cases the state should assist the municipality in tracing down the source of the trouble and obtaining correction, rather than taking punitive action against the municipality and then leaving it to find a solution to the problem.

In connection with this subject, the program of the Allegheny County (Pa.) Sanitary Authority is worthy of note. The following points dealing with industrial wastes are taken from the Authority's January 1948 report, "Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes."

In the letter to officials of all municipalities that have contract arrangements with the Authority, Item 7 states: "Ordinances must be enacted by the participating municipalities to validate the power of regulation and exclusion by the Authority from any public sewers of all industrial wastes which may be injurious to the sewerage and treatment facilities or processes."

The section of the report entitled "Industrial Wastes" contains certain items that bear repetition, as follows:

1. Commenting on the fact that all industries discharging directly to streams were subject to the orders of the Sanitary Water Board: "Those industries, however, which were connected with municipal sewer systems were deemed to be the responsibility of the municipality permitting such connections and therefore such industries did not receive an order from the Sanitary Water Board."

2. "Industry, generally speaking, may separate collecting and condensing water from industrial waste discharges and thus make possible the discharge of these waters into the streams without necessity for treatment." In other places cooling water is included in this category.

3. "The question of whether or not a municipal sewer system should be designed and built to take all industrial wastes including domestic sewage has many advocates on both sides but American practice today, even in the largest of our cities, has resolved itself into the policy of accepting all industrial wastes which are not deleterious to the structures and to the treatment processes on the basis that industrial wastes should not create a burden beyond reasonable limits and not require extraordinary attention or costly designs of both collecting and treatment structures and treatment processes, keeping in mind, however, at all times that no discrimination should be practiced between the various classes of users of the Authority system." In passing it should be mentioned that this refers primarily to building new facilities. When considering discharge to existing plants, it must be remembered that excessive volumes of water would interfere with treatment processes by simply reducing the detention period.

4. "As a matter of policy the Authority has adopted the plan of accepting for collection and treatment all industrial wastes which are found to be of a nature which will not affect adversely the structures nor the treatment processes proposed by the Authority. It is quite obvious, of course, that the greater the amount of domestic sewage available for dilution purposes the greater the quantities of industrial wastes that can be accepted and neutralized as a result. . . ."

III. INDUSTRIAL VIEWS

By Raymond W. Hess

National Aniline Division, Allied Chemical and Dye Corp., Buffalo, N. Y.

There seems to be general agreement that there should be control over the quality and quantity of industrial wastes discharged to municipal sewer systems. This is because many industrial wastes differ so greatly from sewage in quality and in quantity from a single source. There seems to be general agreement, also, that the reasons for this are as follows:

1. To avoid damage to municipal installations.
2. To avoid injury to treatment processes.
3. To avoid fire, explosion, and toxicity hazards to the public generally, and especially to workers in the municipal system.
4. To avoid overloading the municipal system.
5. To avoid impairment of waters which receive effluent from the municipal system.

There is disagreement as to what should be the nature of this control. Some propose rigid limits to the concentrations of specific materials in process effluent (such as acids, alkalies, phenols, cyanides, metallic ions, oils, suspended solids, and those having a high B.O.D.). This is not realistic, as concentrations above the limits in small volumes could be harmless while large volumes of wastes which meet specification limits could be harmful.

A considerably different proposal is offered. There should be no rigid specifications for process effluent, excepting possibly for a few substances. Whether or not the effluent will damage installations depends not on the properties of the plant effluent, but on the properties of the mixtures of wastes and sewage in the sewer system. Whether or not it will be injurious to treatment processes depends not on the properties of the plant effluent or even on the properties of its mixtures with sewage in the interceptor, but on the properties of the mixtures in the sewage treatment plant after being mixed with sewage from all interceptors. It is well known that the properties of these wastes in the sewer system are altered by dilution and reaction with sewage. Whether or not it will be injurious to the stream depends on what happens to it by dilution and reaction with sewage and by treatment at the municipal plant.

The manner in which the characteristics of an industrial waste are altered by mixing with sewage at the treatment plant is exemplified by the sharp drop of chlorine demand in some cases. This fact has now been recognized by the Tenth Edition of "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes."

The success of such a procedure for controlling the quality and quantity of industrial wastes discharged to the public system depends on the close and conscientious cooperation of industry with the sewer system officials. Furthermore, such a procedure is likely to be more successful and less costly than that of having an elaborate list of rigid specifications for process effluent.

Under this plan it is very helpful for industry to have its own experts on waste treatment and water pollution problems. First, they should become thoroughly acquainted with the public waste treatment system and the quality requirements of its effluent to receiving waters. Whenever consideration is being given to the discharge of a waste to the public system its properties should be tested after mixing with sewage, at interceptor dilution and at treatment plant dilution in relation to the effects of its mixtures on structures, treatment processes, hazards, loading, and

requirements of treatment plant effluent to the stream.

If found to be harmful in any of these respects, consideration and possibly research should be given to determining if the waste could be made harmless to the public system by partial treatment, to economic advantage in comparison with other methods of disposal. At this stage it might be decided that it would be economically advantageous to treat the waste to the extent required and discharge directly to the stream, or to modify the production process to avoid formation of objectionable components in the waste liquors.

If such a line of investigation indicates that the waste, after preliminary treatment, if required, can be discharged to economic advantage to the public system without harmful effects, a sample of the waste with information as to volume should be submitted to the sewer system officials for their tests and report on acceptability and cost of acceptance.

Exceptions for which rigid concentrations limits in process effluent might be set, appropriately, are certain toxic, inflammable, and explosive substances, which can be readily diverted from the sewers. Included among these are cyanides and undissolved hydrocarbons, such as benzol and gasoline, which have ignition points at ordinary temperature.

Slugs of cyanide liquors might result in extremely toxic fumes being evolved in and from the sewers. These also may result in erratic chlorine demands at the treatment plant, making destruction of cyanide and adequate disinfection impossible. These slugs could be prevented by controlled discharge, but in view of the ease of treatment it might be better to set specifications for cyanide concentrations in the process effluent.

Volatile hydrocarbons can cause explosions which are disastrous not only to the sewers but also to structures and people on the ground surface. A sewer blast in Cleveland, Ohio, in 1953, attributed to such substances, killed one person, injured 64, and caused property damage estimated at $6,000,000. It is relatively easy to keep these substances out of the sewer because of low solubility and ease of phase separation.

Discussion of capital and service charges for accepting industrial wastes into municipal systems is such a comprehensive and complicated matter that volumes could be written on it and still leave much to be said. Accordingly, only a few of the high points are touched on here.

Among the methods which have been adopted or proposed are the following:

1. The older method of financing from the general fund.
2. The more recent trend toward revenue bonds for capital expenditures and service charges to amortize bonds and meet operating expenses, by a public agency.
3. Contributions by industry to the cost of building and operating a municipal plant that receives industrial wastes.
4. Formation of a waste treatment corporation, in which both industry and the municipality participate.
5. Erection and operation by industry of a process wastes treatment plant, which receives municipal sewage for a service charge.

It is surmised that what is best for a community depends on local, legal, economic, and social circumstances. The validity of this and the factors involved would seem to be fitting for discussion.

The Buffalo plan, which comes under the revenue bond and service charge category, seems to be generally satisfactory locally. The process includes primary treatment, chlorination, sludge digestion, and sludge burning. The Buffalo Sewer Authority was established to finance, build, and operate the

treatment system until amortized, when it may be turned over to the city. Operating costs are met by both property and sewer taxes. The basic sewer tax is for volume and has a progressively lower rate for higher volumes. The rates are higher for wastes having higher concentrations of suspended solids and higher chlorine demands, and are based on costs of handling suspended solids and of chlorine requirements in excess of those for sewage.

In summary, the present items for discussion are the problems of controlling the quality and quantity of industrial wastes discharged to public treatment systems, and the methods of financing the costs of treatment.

IV. MUNICIPAL TREATMENT

By George F. Fynn

Works Superintendent, Buffalo Sewer Authority, Buffalo, N. Y.

The "Glossary: Water and Sewage Control Engineering" defines sewage as "largely the water supply of a community after it has been fouled by various uses." From the standpoint of source it may be a combination of the liquid or water-carried wastes from residences, business buildings, and institutions, together with those from industrial establishments; and with such ground water, surface water, and storm water as may be present. Industrial wastes are designated as the liquid wastes from industrial processes, as distinct from domestic or sanitary sewage.

In a consideration of operation of a sewage treatment plant handling industrial wastes there are two basic concepts: (a) the situation wherein an existing sewage treatment plant is faced with the problem of proper operational procedure hampered by the introduction of a new industrial waste from a recent additional plant in the area, or a revision of plant processes or expansion of facilities to handle new products; and (b) the construction of a new sewage treatment plant in an established community where facilities had not existed formerly.

To ensure a minimizing of any usual problems, the basic requisites are cooperation, research, and education. If an industrial plant is to expand or change production processes, consideration should be given to any adverse effect of new industrial waste upon the treatment plant. All agencies in any community should be familiar with the general over-all facilities in the municipal structure. For example, one group may direct efforts to procuring new industry in a locality. What bearing would the attainment of this goal have on water resources and waste disposal? Any accrual of added revenue may well be offset by the unsatisfactory results of sewage treatment processes or necessitate added expenditures to enlarge or revise existing facilities. Research and education with suitable cooperation could well forestall the placing of an insurmountable obstacle on a sewage plant staff.

With the construction of a new sewage treatment plant, a thorough preliminary study of the maximum loads, in addition to various possible undesirable components, should lead to the erection of facilities that can cope satisfactorily with the demands placed upon them.

Establishment of a national set of standards for effluent discharges from industrial plants would create a utopia whereby maximum efficiency and the ultimate in treatment would be a continuous accomplishment. Even though such a goal might be attained, problems would still arise from the surreptitious activities of some industrial plants.

Continuous policing of a sewer system is not feasible nor practical to pinpoint offenders, although provision for the dispensing of severe penalties for infractions should be established.

In the over-all picture relative to industrial wastes, there should be exclusion of materials that would tend to obstruct the sewers, deteriorate the structures, hinder proper operation of plant facilities, or contain a substance that would be injurious to the public health. The most critical components of an industrial waste discharge are oils and greases, flammable materials, and toxic and corrosive substances. Of recent origin, to be added to the foregoing, are radioactive materials. A definitive limit on concentrations contained in discharges should be established and all industrial plants alerted to the existence of such regulations.

In any consideration of this subject the economic phase must not be overlooked, because industry is the life blood of a community and the promulgation of goals impossible of attainment could result in the growth of ghost towns. However, there is a definite result to be sought from the operation of a sewage treatment plant; if undue burdens are placed upon the facilities, there is a needless waste of money in attempting to accomplish something that is in the realm of the impossible. A happy medium should be struck between the idealistic view and the practical aspect.

The City of Buffalo is noted for its diverse and varied industrial activity. The sewer system is a combined one consisting of some 775 miles of lines. All of the industrial wastes, with the exception of some of those from five industries on the Buffalo River and a small area in the southwest section of the city, are received at the treatment plant. During the construction period a rather extensive survey of the industrial plants was conducted to furnish information as to possible maximum loads to be handled at the plant. The principal waste producers tributary to the city sewers include the packinghouses, tanneries, breweries, rubber and rubber reclaiming plants, and miscellaneous industries such as dairy products, chemical products, canning and food products, metal specialties, etc. With the type of sewage treatment provided at the plant, the industrial wastes are not as critical as at plants providing complete treatment. Industries are to be kept under observation and all reasonable means used to keep down the suspended solids and chlorine demand, as these items affect materially the cost of treatment plant operation.

Pretreatment of industrial wastes consists mainly of neutralization of acid discharges, installation of oil and grease traps, and chlorination of some wastes from metal plants, especially when cyanide may be a factor. The total volume of industrial wastes is estimated as being 25 to 30 per cent of the total volume of sewage handled. Buffalo has a high water consumption rate per capita and dilution plays a vital role in a consideration of the possible adverse effect of certain constituents of an industrial waste.

Basically there are two charges assessed against owners to obtain revenue for meeting the financial requirements necessary to maintain sewer authority functions. One is a charge for sewer service based on water consumption; this contributes approximately 42 per cent of total income. The other is a sewer rent based on assessed valuation of taxable real estate; this constitutes about 53 per cent of the total resources. From the basic fact that the cost of operation and maintenance of any sewage treatment works is directly affected by the quantity, character, and strength of sewage, the fairest and most equitable distribution of payment for the costs of sewage treatment is the sewer rental system whereby the user pays for services rendered proportional to the benefits derived. Based on this premise, the Buffalo Sewer Authority established a special sewer serv-

ice charge for industrial wastes, with the cost of chlorine, chemicals, and power for the disposal of solids as the main factors in the construction of a formula for the determination of excess charges. A detailed account of this program was published in the March 1944 issue of *Water Works and Sewerage*.

To obtain information as to new sources of industrial waste, applicants submitting requests for the construction of waste disposal facilities to the Division of Plumbing and Drainage are furnished a questionnaire to be forwarded to the Authority office. This form contains questions dealing with the volume and character of waste discharges and constitutes a source of information for special investigations.

The most serious difficulties encountered in plant operation have been caused by the introduction of materials of solid nature rather than liquid discharges. Some instances of such character were the appearance of several tons of barley deposited in the grit channels, an assortment of thousands of corks, an abundance of foam rubber buttons, and the introduction of several thousand gallons of a tarry asphaltic material. The latter case furnished an excellent example of industry's cooperative attitude when the company responsible for this situation supplied a labor force to remove the objectionable material from the various parts of the plant units.

The dissemination of information to the treatment plant personnel in the case of an inordinate discharge of a waste or a major breakdown in an industrial process, that might result in a temporary overload of the plant facilities, is a major factor in being prepared for emergency action. Prompt action on the part of a sewer crew noting an unusual condition in any portion of the sewer system will also tend to amass information that will aid materially in overcoming improper waste discharges.

Neutralization of acid-type wastes, installation of suitable equipment for the removal of oils and greases at the industrial plant, prevention of the discharge of bulky material that may tend to clog sewers, chlorination of some liquids, and the release of wastes over an extended period of time rather than in batch doses, are basic considerations in handling industrial wastes at the source. The cost of cleaning sewers should be borne by the industry responsible for the inordinate discharge of material resulting in blockages. Some older industrial plants are handicapped by the lack of suitable or sufficient land area for the construction of desirable pretreatment facilities, and such situations must be considered individually to effect a beneficial solution.

Close cooperation between the treatment plant personnel and representatives of industry is a necessary requisite to ensure a mutual understanding of existing problems. Under such an arrangement, education and research will aid materially in alleviating shock loads that may be detrimental to the proper operation of treatment plant functions.

V. AN INDUSTRY'S EXPERIENCE

By A. J. Gabaccia

Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

Lederle Laboratories Division of American Cyanamid Company is located in Pearl River, N. Y. The waste effluent from Lederle discharges into the Pearl River Sewer District. This waste treatment arrangement with the Town of Orangetown was initiated in 1940. Prior to this and going back to

the 1920's, Lederle's waste was treated by activated sludge, trickling filter, chlorination, and the effluent was discharged into a nearby brook.

By the late 1930's both the city of Pearl River and the Lederle Division (the largest employer in the area) had grown to the point where waste disposal presented a problem. The brook became inadequate for Lederle and the septic tank became inadequate for the people of Orangetown. It seemed a very practical solution for both parties to combine forces in solving their waste disposal problem. When the Town Board of Orangetown approached Lederle to join them in a sewage treatment plant, Lederle was very much in agreement.

A contract was signed in June 1939. The contract called for the town to build a treatment plant and a collection system. The plant was designed to treat 900,000 g.p.d., of which 300,000 g.p.d. was reserved for Lederle. This sewage plant consisted of primary settling, low-rate trickling filters, sedimentation, digestion of sludge, and sludge drying beds. In the spring of 1940, the sewage plant was started.

Between 1940 and 1948, Lederle agreed to pay for the installation of a second sludge drying bed, insulation of the digesters, and construction of additional primary settling tanks.

In 1949, American Cyanamid proceeded to increase the waste disposal facilities at the Lederle industrial waste plant. By 1950, two 100-ft. diameter trickling filters, equipped with 85,000-gal. clarifiers, were built. A third unit and a final clarifier were completed in 1951. Under this treatment pattern, Lederle waste received pretreatment on trickling filters, combined treatment with municipal waste on the town trickling filters, and then it was discharged into the Hackensack River.

In 1952, Lederle initiated a program calling for the removal of the town's effluent from the Hackensack watershed by pumping to the Hudson River. A 12-in. Transite force main approximately 3 miles long was run between the town plant and the 36-in. concrete and wood-stave pipe formerly used as the effluent line from the old Camp Shanks sewage plant. The cost of this force main was financed solely by Lederle. At the town sewage plant, the effluent is pumped into the force main by three pumps, which can be operated in series or in parallel. The capacity of these pumps is 600, 900, and 1,200 g.p.m. In the 36-in. concrete line to the Hudson River, Lederle has a capacity of about 6 m.g.d. and the town has 2 m.g.d.

Under present production schedules, the Lederle waste treatment plant handles about 900,000 g.p.d. with an influent B.O.D. of about 1,000 p.p.m. The final effluent prior to discharge into the municipal sewer has a B.O.D. range between 30 and 130 p.p.m. Ten tons of wet sludge cake are filtered and composted every work day. One senior and three junior operators provide round-the-clock attention to the Lederle waste plant. In addition, two laboratory chemists and two engineers are assigned to this department. The monthly charges, including all overhead charges plus payment for town sewage charges amounts to about $30,000. Unit costs can be stated as about $0.40 per pound of B.O.D. treated, or about $7.00 per Lederle employee per month.

The town plant handles about 40 m.g. per month, of which Lederle's flow is about 50 per cent, or 20 m.g. per month. The town's influent B.O.D. is about 250 p.p.m., and the effluent which is pumped to the Hudson River has a B.O.D. of less than 40 p.p.m. The town's yearly costs run about $100,000 per year, with Lederle sharing about 55 per cent of this, or about $55,000 per year. Under the present 10-year contract, the payment of expenses is divided into three categories. The first is paid solely by the town, and includes the following items:

1. Power cost in the town pump station.
2. Insurance for town pump station and manholes.
3. Debt service; about 36 per cent of 1939 bond issue and later issues.
4. New connections and lateral maintenances.

These items amount to about $15,000 per year.

The second category is shared on a volume basis by Lederle and the town, and includes the following items:

1. Chlorine costs.
2. Power costs.
3. Miscellaneous supplies.
4. Truck maintenance.
5. All salaries and labor costs.
6. Telephone.
7. Insurance and workman's compensation.
8. Contingencies.
9. Debt service; about 64 per cent of 1939 bond issue.
10. Sand.
11. Taxes.

This totals about $65,000 per year.

The last category covers cost items paid solely by Lederle, and consisting of the following:

1. Power over 100 kw-hr. per million gallons.
2. Labor over 25 man-hours per million gallons.
3. Insurance rates on 1951 construction.
4. Contingencies on 1951 construction.
5. Taxes on 1951 construction.

This totals about $22,000 per year.

The required calculations are made by the superintendent of the town sewage plants, and the annual bill is submitted to Lederle some time in February. Lederle pays the town in advance one-half of the estimated cost at the end of February and the second half at the end of August. In addition to this annual cost report, Lederle receives a weekly and monthly report recording B.O.D., flow, and solids quantities. A copy of the monthly report is sent by the town to the New York State Department of Health.

The relationship between Lederle and the town on sewage treatment is very good, and Lederle hopes and believes it will continue. With Lederle's effluent discharging into the municipal sewer at a B.O.D. of about 50 p.p.m. and with the town's effluent discharging into the Hudson River at a B.O.D. less than 50 p.p.m., the relation between the town and the state health authorities is very pleasant.

VI. THE CASE AGAINST

By Charles C. Spencer

Director, Division of Environmental Sanitation, Erie County Health Department, Buffalo, N. Y.

The practice of discharging industrial waste to public sewers had been assumed by the author, and many others, to be a logical practice. However, after a short review of the subject, it appears quite as logical to conclude, at least for this discussion, that it is usually unwise to add industrial waste to public sewage treatment systems.

The decision on whether or not to sewer industrial wastes will depend upon the character of both the municipality and the industry. The nature of the receiving stream must also be considered. Where a treatment plant

has been installed to maintain a certain quality in the stream it is frequently undesirable to accept any waste which may jeopardize treatment efficiency, temporarily or permanently.

Many cases are on record where industrial wastes in city sewers have nullified the performance of pollution abatement measures undertaken after prolonged efforts by control agencies and involving heavy public expenditures. Too often, city officials fail to realize what troubles they may expect from industrial connections. The practice may be expected to cause more problems than it solves.

Sometimes the adverse effects on municipal plants are so transitory that it is almost impossible to determine their significance, and elimination of the difficulty must await repeated offenses. In these instances much damage can be done before the responsible industry can be identified and asked to correct the problem.

In New York State it has been the practice to hold the municipality responsible for pollution by industrial wastes reaching waterways through public sewers. When difficulty arises the municipality has no direct control over the source of waste and must sometimes negotiate over an extended period to find a means of correction. Frequently, the municipality is reluctant to take prompt action against an industry which is contributing substantially to the local economy.

It has been Buffalo's experience that it is more effective to discuss necessary corrective measures directly with the industry producing the offending waste. They are usually quick to understand the problem and are in the best position to evaluate possible remedies. It is easier for them in many cases to provide necessary funds for the purpose than may be the case with a tax-supported utility.

It has been found with new municipal plants that industries often can not accurately predict the amount and character of their waste or its variability. This renders plant design uncertain. Production may increase after completion of plans for treatment, so that a new municipal plant is inadequate as soon as constructed.

This happened recently in Erie County at a village plant designed to accept some milk waste. Large unexpected amounts of whey reaching the new plant kept the trickling filters from operating properly for several years. Management of the dairy responsible promptly agreed to cease dumping whey, but trouble continued due to carelessness or misunderstanding on the part of foremen and employees.

Theoretically, it is possible to control the quality of industrial effluents within limits which offer no hazard to the treatment plant or stream. Experience is so often to the contrary that municipalities should accept industrial discharges only under the most secure guarantees regarding quantity, strength, and variability.

Routine industrial operations may cause no problem, but accidental spills or dumping of defective batches of product may be dangerous or extremely destructive. One large plant in Erie County spent more than $1,000,000 on a plant to remove oil and grease, but still finds oil in its effluent because workers persist in dumping waste oil into storm sewers instead of waste sewers. Another very large plant provided treatment facilities and holding tanks for waste in the event that these treatment units were out of service. Unfortunately, when the latter occurred the holding tanks were in use for a different emergency, and the untreated waste reached the stream almost directly.

In Niagara Falls great difficulty has been experienced from dumping of dangerous liquids into the sewers. In some areas it is necessary to build stacks on manholes to carry fumes above street level.

The importance of accidents, leaks, and other factors sometimes beyond the control of management cannot be exaggerated in this discussion.

In July 1952 an incident occurred in Indiana (THIS JOURNAL, **26**, 11, 1382; Nov. 1954) wherein 3,000 lb. of sodium cyanide were accidentally dumped to city sewers by a plating concern. This slug killed practically all aquatic life in the Wabash River for a distance of almost 60 miles and was not spent until it had almost reached a public water supply intake. As a result of this occurrence, Indiana now has a regulation stating that no room where cyanide or cyanogen compounds are used may be connected or have access to a sewer or stream. Protection can be provided by curbing, holding tanks, pits, etc., so that accidental tank overflows or dumps can be caught and disposed of in a safe manner.

Any plant handling concentrated acid, cyanide, or dangerous waste of a similar nature should be required to have protective devices of this nature to prevent harmful discharges. In many cases, provision of a holding tank will permit bleeding the waste at a low rate into the sewer or stream to avoid damage.

In Buffalo, the sewage plant is designed to disinfect sewage for the protection of downstream water plants. At times, cyanide and other compounds have reached the plant in sufficient amounts to exhaust the chlorine applied. In such cases sewage has not been adequately disinfected. It is not always possible to trace the origin of these unacceptable materials and the consistent performance of disinfection, therefore, cannot be quaranteed.

There have been other times at downstream water intakes when excessive chlorine demands due to industrial wastes have caused insufficiently chlorinated water to be distributed to the public. Such an instance could result in an epidemic.

Troublesome conditions also have arisen at Buffalo due to oil wastes reaching digesters and stopping their action. In fact, all local treatment plants serving industry are severely affected by such wastes, at least occasionally.

Instances of difficulty at municipal plants due to industrial wastes are familiar to all. A few additional examples may be cited.

Prior to construction of a village plant in Erie county a few years ago, surveys indicated a pH variation in one industrial sewer ranging from 2 to 14. This was called to the attention of the designing engineer, with a request that pretreatment be required. The industry concerned was requested to do so and promised cooperation. Five years later the plant structures are still being destroyed by acid. No violation of stream standards results, therefore state pollution laws do not require cessation of the acid. Where such a condition causes extensive damage over a period of years it is usually not practical to charge the entire cost to the industry responsible.

In one upstate New York city an activated sludge plant to serve 30,000 population was constructed in 1940. Within five years an industry was established in the area with a waste equivalent to more than 60,000 persons. In addition, it discharged a toxic compound which nearly stopped operation of the activated sludge units. For some time the nature of this toxic compound could not be discovered because of certain patent problems involved.

Further industrial growth in this district now causes the population equivalent reaching the plant to vary from 150,000 to 250,000. It is recognized that the operation of activated sludge units becomes almost impractical when the organic load varies more than 50 per cent in a few hours.

The improvements and increased costs made necessary by industry in a plant of this type can seldom be charged to the industry in the justified proportion.

At the present time, increasing costs

are rendering construction and maintenance of public sewers a critical problem. In this connection a city faced with the need to improve its facilities may reduce necessary expenditures by excluding industrial wastes which are expensive to handle. Costly municipal facilities to serve industry may become worthless if the industry changes its operations or moves away. Of course, it is also necessary to consider industry's contribution to the local economy.

In summary, it may be said that cities have been overly optimistic in accepting industrial wastes and that the practice must be seriously questioned from the viewpoint of economics, public health, and sewage treatment technology.

REPORT ON THE NTTCIW MEETING, DECEMBER, 1956

The National Technical Task Committee on Industrial Wastes (NTTCIW) heard task group reports and learned about the new Federal Water Pollution Control Act (P. L. 660) during its 1956 meeting at the Mellon Institute of Industrial Research, Pittsburgh, Pa., on December 13–14, 1956. This Committee is a voluntary group formed to work with the USPHS on technical control of water pollution by industrial wastes, thereby protecting the water resources of the United States. Professor C. Fred Gurnham, head of the Department of Chemical Engineering, Michigan State University, presided.

Gordon E. McCallum, Chief, Water Supply and Water Pollution Control Program, USPHS, emphasized that the principal resource problem facing the nation was the conservation of water resources. Public Law 660 increases authorizations of money for research, and state and interstate aid in pollution control. However, much of the water quality data needed for economic evaluation of pollution control needs and related federal grants is lacking.

The general sessions centered on problems of mutual interest to the task groups. H. G. Hanson, Director of the Robert A. Taft Sanitary Engineering Center, discussed the industrial wastes problem and the need for a costly long-range program to meet the increasing demand for good quality water. He emphasized that an enormous amount of research is required to characterize the effects of industrial wastes, especially those from the rapidly expanding synthetic organic chemical industry. R. W. Hess, National Aniline Division, reported on the scope of research activities recommended. Numerous projects have been proposed for present and future study. The Research Personnel Subcommittee reported on the continued shortage of adequately trained personnel, apparently caused by the exacting training required and the inadequate salaries. The punch-card bibliography was discussed in light of an improved method of coding the cards, but interest in the system was lacking. Continuation of the NTTCIW News Quarterly, which has been well-received, was approved. However, a system of financing the publication was deemed of utmost importance, since at present the cost of publishing the Quarterly is borne by a sponsor from industry. G. A. Aikins reported on the difficulties experienced by the Subcommittee on Pollution Control Expenditures by Industry in obtaining data. The Municipal-Industrial Treatment Subcommittee reported than an extensive survey was being made on the subject of municipal-industrial treatment.

The four task groups of NTTCIW reported in separate sessions on their accomplishments and proposals for the abatement and prevention of water pollution. The food industries group reported progress through recovery and use of by-products, spray irrigation, and biochemical treatment. The mineral products group reported on development of an effective type of dephenolizer and improved handling of uranium processing wastes. Progress was reported on the revision of manuals, including the flue-dust recovery manual, and the preparation of a water quality criteria by the petroleum industry. Recommendations on the phenol problem were being prepared by the steel industry. The chemical processing group heard reports on work with wastes in the nuclear energy industry, the extension of ion exchange treatment methods by the electroplating industry, an the use of incineration by the paint industry. Extensive research work by the pulp and paper, and the soap and glycerine industries was described. The general industry group indicated progress in the biological treatment of phenolic wastes and cyanides. Considerable discussion was centered on the use of Dowpac in biofilters and cooling towers. Several industrial installations were discussed, and it was reported that research work was underway at two institutions.

Officers elected for 1957 were: Frank McKee, Kraft Foods, Chairman; Richard D. Hoak, Mellon Institute, Vice-Chairman; Louis F. Warrick, USPHS, Secretary.

Stream Pollution

THE ROLE OF THE STATE WATER POLLUTION CONTROL AUTHORITY *

By David B. Lee

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The matter of establishing waste disposal requirements at one time seemed to be a relatively simple matter. But, as the population increases, the uses and importance of water increase and the problem is seen to be more complex. In spite of this more people today are urging the lowering of waste disposal requirements than ever before in history.

The reasons for focusing nationwide interest on water resources conservation, including water pollution control, are well known but worth emphasizing here. Population has more than doubled since 1900 and is continuing to increase at a rate of more than 2 million a year. Industry has grown 700 per cent in the past 50 years and is expected to double again by 1975. As a result of these increases, water use in the United States since 1900 has more than doubled each 25 years and is expected to double again by 1975. Water use, in most cases, results in deterioration of water quality; that is, pollution. The problems of controlling pollution, therefore, increase at a rate which equals, and perhaps exceeds, the rate of water use. According to data compiled by the USPHS, organic pollution discharged from municipalities is presently equivalent to wastes from 55 million people. The industrial organic pollution equivalent has been estimated to be even greater.

In 1955 we were using more than 262 billion gallons of water per day in this country. About 22 billion gallons of this amount were used for rural and public water supplies and the balance was used for irrigation, manufacture of electric power by steam, and industrial and miscellaneous purposes. It is estimated that water use will exceed 453 billion gallons per day by 1975. All of this water must be of reasonably good, non-polluted quality. While there are, unfortunately, still a few who believe that "the solution to pollution is dilution," it is probably safe to say that the great majority of responsible sanitary engineers agree with Mark Hollis, Chief Engineer of the USPHS, that "the dilution of pollution is no longer the solution." In spite of this, however, administrators of water pollution control programs continue to get numerous requests from every kind of technical and industrial interest to lower waste disposal requirements. As one of these administrators, the author has been requested to review these requirements and offer his conclusions on the role of the state in determining water pollution requirements.

Conflicting Uses of Water

The state regulatory agency serves as the umpire in the game of water

* Presented at the 1956 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Chattanooga, Tenn.; Sept. 17–19, 1956.

pollution control. The teams in this league, each intent on gaining its own worthwhile goal, are:

1. Public water supply agencies who would like to maintain every stream in a state of pristine purity, without turbidity, color, taste, or bacteria, so that water could be supplied to the public with a minimum of treatment.

2. Public wastes disposal agencies who would like to have access to any available stream for the disposal of wastes with a minimum of treatment.

3. Industrial users who frequently need purer water than is needed for usual public water supply.

4. Industrial establishments requiring waste disposal who would like to look on the streams as the natural receivers for all liquid wastes with the minimum of treatment or with no treatment.

5. Fishing and Wild Life Conservation groups who look on every waterway as a natural resource primarily for the propagation of fish and wild life.

6. Nature lovers who view every quiet pool and every trilling brook as a national treasure to be guarded against all trespassers.

7. Agriculturists who sometimes seem to want to irrigate all dry land with pure wholesome water and at the same time to drain all wet land without undue expense.

8. Cattlemen who object to the elimination of waterways or to the pollution of water used for stock watering but who also insist on their right to drain needed pasture land.

9. Power interests who value a flowing stream primarily as a potential source of power.

10. Shipping interests who maintain that the main function of water is to float boats.

All of these teams play a good game; all have worthwhile goals and able and energetic players. Obviously, however, while they are sometimes playing together they all too frequently are playing against one another.

We do not mean to imply that the water pollution agencies can solve all of the problems arising from conflicting interests, or that they should be called on to arbitrate matters outside their field. Water pollution is only one facet in the sphere of complete water conservation and use. However, at one time or another all of the interests listed above become involved with water pollution and it is the responsibility of the state water pollution control authority to arbitrate impartially differences which arise when pollution, potential or actual, affects a legitimate use of the water.

Role of Health Departments

Health departments became the first water pollution control agencies because of the basic conflict which arises when it is desired to use certain waters as sources for public water supplies and the same waters as depositories for the public sewage. Disease implications are too well known to deserve more than a passing mention but it should be pointed out that, although modern water and sewage treatment has accomplished wonders in the elimination of water-borne diseases, the need for vigilance is by no means eliminated. The present generation has never had occasion to develop the partial immunity to typhoid and paratyphoid fevers which possibly was responsible for the survival of our forefathers. Florida residents can testify to the fact that a modern water treatment plant can be overloaded with sewage pollution. Due to failure of a Florida sewage treatment plant discharging to a lime rock sink, a nearby water-softening plant, including sand filters and chlorination, was so overwhelmed that the M.P.N. of the finished water exceeded 70,000 coliforms per 100 ml. Only the lack of a source of pathogens, and perhaps the use of boiled water, protected the populace during this period.

However, as the United States has become more highly industrialized and the uses of water have become more diversified and complex, water pollution has come to be regarded more as an economic problem or a matter of conservation than as a public health problem. Health departments, usually controlled by boards of medical doctors, have been slow to assume the role of arbitrator unless actual disease transmission is involved. As a result, an increasing number of states have created independent water pollution control agencies.

In Florida, however, it is felt that public health is still the paramount reason for water pollution control and that, where independent agencies are created, the health department is unable to maintain the close control which its responsibilities require. If the two agencies are closely associated and coordinated, this loss of control may be minimized but there is still a chance for failure due to divided responsibility. On the other hand, it must be admitted that it is sometimes difficult for a public health agency properly to evaluate a major industrial expansion program and balance its value against the loss of a fishing stream or the occasional death of fish. It would appear that the reasonable approach would be the establishment of a water conservation board with over-riding powers to coordinate the activities of all of the several agencies involved in water use. This would mean that a fish and game commission would continue to be responsible for fish protection and a health department for water pollution control but, where a conflict of interests existed, the water resources commission would act as the arbitrator.

Health Departments and Industrial Wastes

That the health department has more than a passing interest in industrial waste disposal can be demonstrated by one or two actual examples. The classic case is the situation in which organic pollution from an industry so depletes oxygen resources that pollution from a source of domestic waste is carried farther downstream. This has not been a major problem in Florida largely because there are no polluted streams that are long enough to permit the oxygen sag to reach its lowest point before the stream discharges into the ocean or the Gulf of Mexico, but this problem does occur in many other areas. Another definite relationship between industrial waste and public health exists where toxic substances are discharged into waters reaching public water supplies. Many states have been involved in health problems arising from the discharge of cyanide and other plating wastes and phenols into rivers and streams. Sulfides and mercaptan have also long been sources of tastes and odors in water supplies. In recent years Florida residents have been exposed to a threat from another source. In the manufacture of triple superphosphate, salts of fluorine are released in wash water or are absorbed from stack-gas washers. Two such plants discharge into a stream used as a source of water for a public water supply. So far, the resultant fluoride content at the water intake, amounting to 1 to 5 p.p.m. of fluoride ions, expressed as fluorine, has been reduced by the conventional coagulation and the sand filters to 0.5 to 1 p.p.m. This is well within the range considered desirable for protection of teeth and close supervision of the industrial waste appears to have the problem under control. But the possibility of heavy "slugs" being discharged accidentally is a matter for some concern.

Control Methods

The methods which water pollution agencies should employ to obtain desired results are always subject to debate and discussion. Should stream classification, stream standards, effluent standards, or no standards be

established? Many states now favor a method of stream classification whereby, after adequate public hearings, the water pollution control authority allocates streams, or parts of streams, for certain best uses and designates the standards required for those uses. This has the advantage of insuring that everyone knows what is required but it has the disadvantage of making it difficult to raise standards to a higher classification. Effluent standards are easiest to enforce because this method eliminates the need for extensive stream surveys though it may fail to take full advantage of the self-purification powers of a stream. Effluent standards impose the same requirements on a company fortunate enough, or wise enough, to locate on a large stream as are required of a competitor located on a small stream or brook. Stream standards, either with or without formal classification, are much to be preferred over effluent standards. It is necessary to decide what uses need to be protected; then the standards may be set to protect such uses. Classification of best uses is accomplished formally and officially in some states and informally, by mental allowances, in Florida and some other states.

Florida Classification of Streams

Florida has never adopted a formal classification system because of the great divergence of interests which exists. Raising the classification to the level desired by tourist, fishing, and wildlife interests would prohibit the development of industry. Lowering the classification to the level desired by industry and the promoters of industry would just as surely be destructive to tourism, Florida's most productive activity. The present endeavor is informally to classify the streams and set stream standards which, if met, should adequately protect major interests and at the same time leave the door open for an upward classification if this is indicated at some later date.

Industrial Users and Pollution Control

The state water pollution control authority should not be regarded as a liability to industrial waste producers. If an industry is taking reasonable precautions to prevent water pollution, the state agency can be his strongest ally. This particularly is true when several industries are involved and the actions of one or two cause all to be in disrepute. The fact that the water pollution control authority had previously approved its waste treatment practices and that the industry was keeping the authority informed of waste quantity and strength, would go far to protect any industry from the charge of deliberate or negligent discharge of inadequately treated waste. There is a deplorable tendency on the part of some companies to consider water pollution authorities as somewhat friendly enemies who should be told only that which is required and be misled as frequently as possible. A far wiser course would be for the industry to take the authority completely into its confidence, furnish copies of waste records, supply information as to what material should be considered confidential, and ask for cooperation and assistance in finding solutions to common problems. If this were done, any state agency would lean over backward to help the industry and would be of great assistance in case of dispute or litigation with downstream water users.

The state water pollution control authority should have one other important role which far too often is neglected. It should be consulted very early in negotiations for a new plant site. Any agency dealing continuously with water pollution control very quickly collects information on a variety of potential plant locations and is in an excellent position to ad-

vise as to the requirements for waste disposal and the nuisance potential. Frequently, the state agency may know of an alternate site requiring substantially less in the way of waste treatment facilities. Having evaluated all assets and liabilities of each available site, management can then make an intelligent site selection. Water pollution control authorities are constantly battling the consequences of poor choices and are therefore apt to take an objective view of a proposal and to be genuinely interested in helping the buyer to locate properly.

Summary and Conclusions

The role of the state water pollution control authority is to advise, counsel, recommend, and suggest requirements for safe discharge of sanitary and industrial wastes into the surface or underground water supplies. The deciding factor, in each case, is the highest use for which the waters are to be used. Only as a last resort should recourse be taken to legal measures. Water pollution control should be a cooperative enterprise between good neighbors. The law is needed only for the occasional stream bandit who would steal all of the resources for himself without regard to the needs and rights of others. The water pollution control authority should be an impartial arbitrator for the rare serious disagreements in which even good neighbors can sometimes become embroiled.

PROFESSIONAL OPPORTUNITIES

West Virginia—The State Water Commission of West Virginia announces four technical positions available in its state-wide stream pollution control program, as follows:

Sanitary engineers for municipal sewage disposal program. Salary, $5,400 to $6,000 per year; two to four years of experience.

Sanitary chemists for analytical and survey work. Salary, $4,800 to $5,400 per year; one to three years of experience.

Inquiries should be addressed to the West Virginia State Water Commission, 1709 Washington St., East Charleston 1, W. Va.

Ohio—Applications for sanitary engineers to work on state public health programs are invited by the Ohio Department of Health. Positions are as follows:

Sanitary Engineer III, graduate engineer, six years of experience, professional engineer registration. Salary, $7,200 to $8,640 per year.

Sanitary Engineer II, graduate engineer, four years of experience, professional engineer registration. Salary, $6,300 to $7,560 per year.

Engineer-in-Training, graduate engineer, registered engineer-in-training. Salary range from $4,320 to $6,300.

Address inquiries to Personnel Officer, Ohio Department of Health, Columbus 15, Ohio.

Decatur, Illinois—The Sanitary District of Decatur, Ill., is accepting applications for the position of Superintendent, effective May, 1957, to succeed W. D. Hatfield. Salary, upwards from $7,000. Employment benefits available. Complete applications should be addressed to the Sanitary District of Decatur, 501 Dipper Lane, Decatur, Ill.

ORGANIZATION AND ACCOMPLISHMENTS OF THE CALIFORNIA WATER POLLUTION CONTROL SYSTEM *

By A M Rawn and Vinton W. Bacon

Respectively, Chairman and Executive Officer, California State Water Pollution Control Board, Sacramento, Calif.

Significant developments in the fields of waste treatment and disposal, and water pollution control occurred during 1956. Public Law 660, extending and amending the Federal Water Pollution Control Act, was enacted by the Congress. The spirit and letter of the amended Act is the acceleration of water pollution control programs by both state and federal governments. To those associated with regulatory agencies, it seems that expansion, improvement and acceleration should be the enveloping spirit of this legislation. This paper presents some of the California activities in expanding and improving water pollution control within the state.

Administrative Organization

The California Legislature in 1949 (after a three-year study) created a water pollution control program quite different from what might be called "typical" in other states. The legislation divided the state into 9 regions, based on drainage areas.

Each of the 9 regions is governed by a board of five members, each member appointed by the Governor from one of five specified fields of interest (water supply, irrigated agriculture, county government, city government, and industrial waste). The regional boards meet monthly or bimonthly. Day to day activities of each are administered by a regional executive officer heading a technical staff. As regulatory agencies, the regional boards have three principal duties:

1. Prescribing and monitoring waste discharge requirements.
2. Formulating and adopting long-range plans and policies.
3. Coordinating the interests of other agencies.

Under the California decentralized program, these local boards are autonomous for regulatory purposes.

The 1949 legislation also created a state board of 14 members representing the fields of water supply, irrigated agriculture, county government, city government, industrial waste, industrial water use, public sewage disposal, agriculture, fish and game, natural resources, public health, and water resources. The state board is directed to:

1. Formulate statewide policy for control of water pollution.
2. Administer statewide programs of research or financial assistance for water pollution control.
3. Allocate funds for the administrative expenses of the regional boards.
4. Review acts of any regional board which fails to take or obtain appropriate action to correct a condition of pollution.

The success of this decentralized program is demonstrated by the fact that only once during seven years of opera-

* Presented at the 29th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Los Angeles, Calif., Oct. 8–11, 1956.

tion has the state board reviewed the actions of a regional board.

Accomplishments

The makeup of the regional board membership emphasizes the important fact that the California system has been designed to give representation to state agencies and segments of state economy having major interests in water pollution control. What, then, has been accomplished since the system came into being? And what, if any, credit is due the system for such accomplishment?

Recently the state and regional boards had occasion to tabulate the number of California waste dischargers who have constructed significant waste treatment and disposal facilities since 1950. The record shows that 571 dischargers have built new or enlarged sewerage facilities during the past six years. This total included 127 of the 310 California cities, 114 of 265 special sewerage districts, 226 industries, and 104 public institutions. In this period more than $214 million was spent by communities, industries, and public institutions for construction of needed waste treatment and disposal works. For the same six-year period, the total cost to the state for its regulatory program was $2,627,000—slightly more than 1 per cent of the amount spent by local agencies and industries. The preponderance of costs borne by the waste discharger underscores the wisdom of the California Legislature in making certain that local interests have an authoritative voice in water pollution control through membership on the control boards.

The program has enjoyed success and it is believed that substantial progress has been achieved under this system. Nevertheless, the boards for the past year have been planning further expansion of activities, particularly in connection with programs for research and monitoring of waste discharges. Definite plans had been made to expand these programs in the 1957–58 fiscal year. Now, with the aid of a Public Law 660 grant, it is proposed to commence expansion just as soon as funds are made available by the U. S. Public Health Service. Since these immediate program changes depend on a federal grant this year, it may be of interest to know what is being done to implement, at the earliest possible date, the provisions of Public Law 660.

Public Law 660

Section 2 of Public Law 660 requires that the Surgeon General of the U. S. Public Health Service shall develop comprehensive programs for the control of water pollution. To aid the Public Health Service in this formidable task, the regional boards compiled an 83-page list of existing and potential project needs. The document includes the name, address, population, existing sewerage facilities, project requirements, and other pertinent data for 576 cities, special sewerage districts, or public institutions. It also includes a listing of 677 unsewered communities which are likely to need sewerage projects in the foreseeable future. Most of these latter communities have present populations of only a few hundred, and two-thirds of them are in unincorporated territory. In order to expedite the federal construction grants program, the project listing was compiled by the regional boards from their records in less than two weeks. It was filed with the Public Health Service on August 31, 1956.

On September 5, 1956 the state board filed with the Public Health Service in accordance with the provisions of Public Law 660, the California "state plan" for the prevention and control of water pollution. The plan for the current fiscal year was approved on September 13, 1956. The narrative description of the California Plan consists of 11 pages plus 25 exhibits which, by reference, are made

TABLE I.—Points on Basis of Financial Needs

Assessed Valuation Per Capita ($)	Points	Treatment Works Construction Costs Per Capita ($)	Points
0–299	5	0–39	1
300–599	4	40–79	2
600–899	3	80–119	3
900–1,199	2	120–159	4
1,200–1,499	1	Over 160	5
Over 1,500	0		

a part of the plan. One of these exhibits is the aforementioned 83-page list of project needs. Since this list is a part of the approved state plan, any community included on the list is also a part of the plan and, as such, becomes eligible, if it otherwise qualifies, for a construction grant authorized by Section 6 of Public Law 660.

Determining the priority of sewerage projects eligible for these federal grants is another problem, and one with which probably all states are now struggling. Criteria to aid in determining priority must be based on both financial and water pollution control needs of the community applying for a construction grant. The final criteria for California projects has not been established yet, although the state and regional boards are working diligently on this problem. With the understanding that the final answer is still being sought, the present priority criteria may be of interest.

It is presently planned that the criteria will be developed by a point system based on financial and water pollution control needs. A maximum of 10 points could be made by an applicant on the basis of financial need and 20 points on the basis of water pollution control need, which means that the criteria would be weighted 2 to 1 on the side of water pollution control need.

Table I presents the number of points assigned on the basis of financial need. Note that this is divided into two categories: (a) assessed valution per capita and, (b) treatment works construction costs per capita. Under this point system, a community with a per capita assessed valuation of $342 would receive four points. If the per capita construction costs of the proposed project were $97, the community would receive three points under that category.

Table II gives the number of points assigned on the basis of water pollution control need. In this case, the number of points would depend on the severity of the water pollution problem. For example, if a community had its waste discharge requirements set and if it needed treatment works in the immediate future in order to prevent or abate pollution, it would then receive 12 points according to the proposed system. On the other hand, a community under court order to abate a condition of pollution would receive a maximum of 20 points.

A community could receive a maximum of 30 points (10 points from Table I, if assessed valuation per capita was low and per capita construction cost was high, and 20 points from Table II, if a legal order to abate pollution had been issued). Most communities would have a lesser number of the priority points out of the possible maximum of 30 points.

During congressional hearings on Public Law 660, California was classed, somewhat unfairly, as an opponent to the bill because the state board was

TABLE II.—Points on Basis of Water Pollution Control Needs

Extent of Need	Points
Legal order issued to abate pollution	20
Waste discharge requirements not being met	16
Discharge requirements set and treatment works needed in immediate future	12
Discharge requirements not set but needed in immediate future	8
Unsewered community which when sewered could cause pollution	4

seeking amendments which it thought would improve and strengthen the federal act as well as the programs of the states. Before enactment, many satisfactory amendments were made. Now that Public Law 660 is law, the California State Water Pollution Control Board has no further disagreement with it as national philosophy, and California can very nicely integrate its activities with those of the federal government. It is planned to do everything possible to make this new law work and to implement its provisions at the earliest possible date.

Monitoring Program

In its plan for water pollution control, California is embarking on a statewide program of monitoring waste discharges. During the first six years of operation, the regional boards have concentrated on setting regulations for both existing and proposed discharges. The prescribing of discharge requirements is, of course, a continuing activity under the rapid growth being experienced in California. This activity must now be supplemented with a highly developed program of policing and checking waste discharges and receiving waters in order to determine if requirements are being met.

Each regional board has announced its program for checking discharge requirements. The monitoring schedule of the San Diego Regional Board is typical of these programs. For instance, 59 discharges will be monitored in that region initially. All discharges will be inspected one to six times yearly by the staff of the regional board. The staff will collect practically all of the samples for laboratory analysis and will make field analyses on 34 of the discharges annually. Other state and local agencies will make 30 partial laboratory analyses, 56 bacterial analyses, and 13 complete mineral analyses annually. In addition to the checking of specific waste discharges, the regional board will monitor the receiving waters in the vicinity of 26 ocean and San Diego Bay outfalls.

Using both Public Law 660 grants and state funds, the California statewide monitoring program will begin immediately. More than 1,000 discharges are to be checked. It is estimated that this program will cost about $55,000 per year. This is only part of the cost of checking waste discharges, as many dischargers conduct continuous and expensive tests on both effluents and receiving waters.

Discharge monitoring is an important adjunct to the water pollution control program. It demonstrates that receiving waters are being protected for the intended beneficial uses and, equally important, it protects the waste discharger from unfounded allegations that pollution is occurring.

Submarine Outfall Research

More than 125 California coastal communities, including 11 of the 13 largest cities, dispose of sewage effluent (and, in some cases, sewage sludge) through submarine outfalls. Approximately 66 per cent of the sewage and industrial wastes collected throughout the state is discharged, after treatment, to bay or ocean waters. In the San Francisco, Los Angeles and San Diego regions (which, incidentally, account for 62 per cent of the sewage and industrial wastes collected in the state) more than 94 per cent of the wastes are discharged to saline waters.

Many millions of dollars have been spent for submarine outfalls to protect the receiving waters and to insure stable structures. Undoubtedly, even greater sums will be expended for this purpose in the future. The state water pollution control board, together with both waste dischargers and water users, recognized the need for submarine outfall research, not only to

be certain that state waters can continue to safely assimilate increasing quantities of wastes, but also to keep treatment and disposal costs to a minimum. Accordingly, in 1954 the state board entered into a contract with Dr. Erman A. Pearson for a study on the efficacy of submarine outfall disposal of sewage and sludge.

The report of this study (1) recommends eight possible areas of research and investigation. Although not listed in order of importance, they are:

1. Ocean currents.
2. Fundamentals of mixing and dispersion of sewage in sea water.
3. Effect of wind and wind waves on the dispersion of sewage.
4. Viability of sewage bacteria in sea water.
5. Critical analysis of bathing water criteria and monitoring.
6. Specific aspects of the disposal of digested sludge.
7. Factors affecting the stability of submarine pipelines.
8. Effects of wastes on marine resources.

More detail on the subjects recommended by Pearson, and by the individuals who reviewed his report and concurred in his recommendations, have been listed in a table prepared by the executive office of the California State Water Pollution Control Board.*

On September 5, 1956 the state board authorized a $100,000 contract with the Allan Hancock Foundation for Marine Research, University of Southern California, to commence an investigation of the effects of wastes on marine resources. Actually, it is estimated that more than $254,000 will be needed per year for the next four years to adequately conduct the background type of study being undertaken by the Hancock Foundation. The executive staff of the state board has been authorized to negotiate with the federal government, and others having an interest in this research, for joint financial sponsorship of the project. Likewise, the staff has been directed to prepare cost estimates and to draft contracts at an early date for the studies on the viability of sewage bacteria, critical analyses of bathing water criteria, and the development and testing of meters for continuous recording of ocean currents.

Thus, California is initiating and expanding, maybe somewhat belatedly, an extensive research program on the submarine outfall disposal of sewage and sludge.

* Available from the California State Water Pollution Control Board, Sacramento, Calif.

Expanded Functions

Three recent opinions of the California State Attorney General have greatly broadened the functions of the water pollution control boards. Prior to these far-reaching opinions, the control boards were chiefly concerned with water pollution from only two sources, namely, domestic sewage and industrial waste as they are ordinarily considered. Now the Attorney General has ruled (2) that many other types of discharges or operations could result in pollution as defined in the California statutes and, therefore, would come under the jurisdiction of the water pollution control boards. Some of the operations which fall within these rulings are:

1. Drainage from inoperative or abandoned mining operations.
2. Bark, slash, sawdust, eroded earth, and other debris from existing or abandoned logging operations.
3. Garbage, ashes, etc., found in refuse dumps.
4. Return irrigation waters.
5. Interchange of groundwaters at improperly sealed wells.

Of particular significance in these opinions is the ruling that, in the case of an abandoned operation, waste dis-

charge requirements may be imposed upon the present owner of the land on which the discharge originates, even though the pollution results from a past operation conducted by a previous owner of the land.

Although it is still too soon to determine the extent to which these opinions will increase the activities of the control boards, it is apparent that they will bring about considerable expansion of the present program.

Regulations Governing the Proposed Discharge at Hyperion

The City of Los Angeles has plans to change the type of treatment and point of effluent disposal of its sewage. The present treatment plant, which is operating near design capacity, comprises the high-rate activated sludge process and chlorination. After treatment, the effluent is discharged into Santa Monica Bay 5,000 ft. offshore at a depth of 50 ft. Studies by the city have demonstrated that it will be more economical to expand treatment capacity by converting the plant to primary-type treatment and discharging both the effluent and digested sludge far offshore in deep water. Therefore, the city proposes to construct, and has financed, plant conversions; an effluent outfall five miles long will discharge at a depth of 200 ft.; and a smaller outfall seven miles long will discharge digested sludge at a depth of 300 ft. Prior to designing the project, the city requested the regulations of the regional water pollution control board.

The sampling stations for a moni-

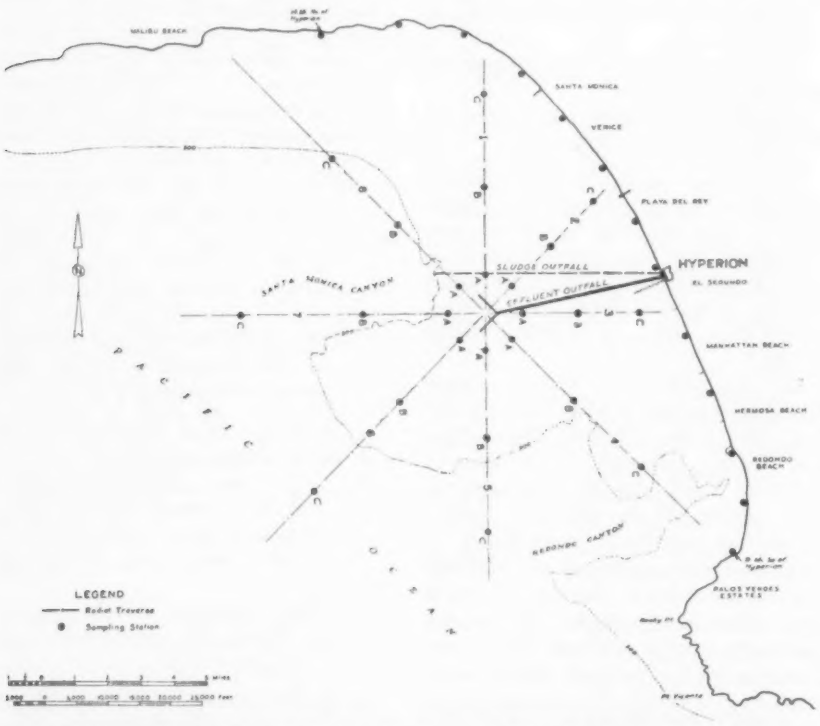

FIGURE 1.—Monitoring stations for proposed Hyperion waste discharge.

toring system to check on the efficacy of the Hyperion outfalls is shown in Figure 1. All of the water area is in Santa Monica Bay. The effluent outfall has a wye diffuser and each wye branch is 4,000 ft. long. The sludge outfall will discharge at the head of a submarine canyon. The present one-mile long outfall is shown as a dotted line near the shore, and is small in comparison with the planned work. The monitoring stations in the offshore area are located along eight radial traverses.

For the purposes of the regulations, the following areas were defined in Santa Monica Bay:

Area 1.—Waters within 5,000 ft. of the nearest effluent or sludge outlet. Conditions in this area are to be monitored at the "A" stations (Figure 1).

Area 2.—Waters and the underlying bottom not included in either Area 1 or Area 3. Conditions in this area are to be monitored at the "B" and "C" stations (Figure 1).

Area 3.—Waters and the underlying bottom within 1,500 ft. of the beaches and shoreline. Conditions in this area are to be monitored at the shoreline stations (Figure 1).

Regulations of the water pollution control boards are based, (a) on the beneficial uses of the receiving waters which are to be protected and, (b) on the water quality conditions which must be maintained to protect the beneficial uses. In Area 1 the principal uses were designated as pleasure boating, commercial shipping, and waste dispersion and dilution. The control board said these uses would be protected if the following conditions, insofar as such conditions are affected by the Hyperion treatment plant discharge, are maintained at the "A" stations:

1. The dissolved oxygen concentration at each of the eight sampling stations shall equal or exceed 6 p.p.m. at all times.

2. Grease concentration, as measured by the arithmetical mean at all eight sampling stations, shall not exceed 2 p.p.m. in any three consecutive samples or in more than 20 per cent of any 20 consecutive samples.

3. There shall be no floating or suspended solids recognizable by eye as of sewage origin.

In Area 2 the principal uses to be protected are propagation of fish and other aquatic life, fishing, recreation such as surfboarding and aquaplaning, shipping and boating, and industrial water supply. As determined at the "B" and "C" stations, waters and underlying bottom must conform to the following conditions, insofar as such conditions are affected by the Hyperion treatment plant discharge:

1. The coliform concentration, as measured by the geometric mean at the two sampling stations along each radial traverse, shall not exceed 100 per milliliter in any three consecutive samples or in more than 20 per cent of any 20 consecutive samples.

2. The transparency at each sampling station, as measured by the Secchi disk, shall equal or exceed 20 ft. in 50 per cent of all readings and shall exceed 15 ft. in 80 per cent of any 20 consecutive readings.

3. The organic matter content of bottom samples, as measured by the yearly arithmetical mean at the two sampling stations along each radial traverse, shall not increase by more than 3 per cent in the total dry solids in any one year. The organic matter content of bottom samples, as measured by the yearly arithmetical mean at the two sampling stations along each radial traverse, shall not exceed 50 per cent of the total dry solids at any time.

4. There shall be no floating or suspended solids recognizable by eye as of sewage origin.

The waters, underlying bottom and adjacent shoreline in Area 3 are to be protected for the highest type of use, including swimming, fishing, picnicking and sunbathing, aesthetic enjoyment, and for an additional 11 recognized uses. As determined at the shoreline sampling stations, the following water quality conditions must be met:

1. The coliform concentration at each sampling station shall not exceed 10 per milliliter in any three consecutive samples or in more than 20 per cent of any 20 consecutive samples.
2. There shall be no grease balls or other accumulations of grease. If accumulations are found about which there is doubt as to whether they contain grease of sewage origin, they shall be analyzed by acidification and extraction. If the saponifiable portion of such extract exceeds 40 per cent, it shall be presumed that the grease is of sewage origin unless further tests prove to the contrary.
3. There shall be no solids recognizable by eye as of sewage origin on the beaches below high water.

Not only did the regional water pollution control board prescribe water uses to be protected, water quality criteria, and monitoring stations, but it also imposed on both the state water pollution control board and the City of Los Angeles a minimum monitoring program. In general, the city must sample and analyze the water daily at the 13 shoreline stations and weekly at the 24 offshore stations. It must also sample and analyze the bottom conditions semiannually at the 24 offshore stations. Further, the city is to conduct prescribed tests daily on the plant effluent and digested sludge. The state must conduct the same sampling and testing as the city but at about one-fourth the frequency. In addition, the state must conduct bioassays semiannually at dilutions equivalent to those normally attained at the outer limits of Area 1.

To further understand this simplified presentation of the Hyperion monitoring system certain precedents in the regulations must be considered.

1. Waste dilution and dispersion is recognized as a beneficial use of Santa Monica Bay within a prescribed area.
2. Only numerical water quality criteria were embodied in the regulations; no general expressions were used.
3. Monitoring on a prescribed schedule and at prescribed points is required of both the discharger and the state far in advance of the actual discharge date. In this case monitoring was required to commence on July 1, 1956, which is probably three years in advance of the actual discharge.

The type of monitoring program embodied in the Hyperion regulations, which is intended to protect both the discharger and water user, is part of the expanding water pollution control program in California.

Now, despite the apparent success which has attended the efforts of the water pollution control authority in California, there are some persons who feel that the law is not sufficiently strong to cope with the situation and that centralization of administration in a single department of state government would be better. An improvement in conditions since 1950 is sensed by most of the regional water pollution control boards, and the existing law and its administration is due some small credit. To a degree the plan is working well. The law is being given a fair trial and despite such criticism as is directed against it, it is gaining momentum. Costs, both for public and private facilities, are being borne locally and control facilities installed

about as fast as may be expected under democratic processes.

Water pollution control is an explosive subject and nearly always expensive to accomplish. There are few simple answers. In California there is confidence that the state water pollution control program is on the right track in this undertaking.

References

1. Pearson, E. A., "An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Sludge." Pub. No. 14, California State Water Pollution Control Board, Sacramento, Calif. (1956).
2. California State Attorney General, Legal Opinions Nos. 55–116, 55–236, and 55–237. California State Water Pollution Control Board, Sacramento, Calif.

MEETINGS OF INTEREST

1957

Mar. 4–8 **Bavarian Biological Institute,** Munich, Germany. Introductory course on biology of sewage and stream sanitation. Bayerische Biologische Versuchsanstalt, Veterinärstrasse 13, Munich 22, Germany.

Mar. 5–9 **American Concrete Pipe Association,** 49th Annual Convention, Shoreham Hotel, Washington, D. C. Howard F. Peckworth, Managing Director, 228 North LaSalle St., Chicago 1, Ill.

Mar. 11–14 **Second Nuclear Engineering and Science Conference,** Philadelphia, Pa. (see page 123).

Mar. 20–22 **Twentieth Annual Short Course,** Superintendents and Operators of Water and Sewage Plants, Louisiana State University and Agricultural and Mechanical College, Baton Rouge 3, La.

Mar. 28–29 **Eleventh Annual Industry-Faculty Conference,** Louisiana State University and Agricultural and Mechanical College, Baton Rouge 3, La. Frank T. Carroll, Jr., Assistant to the Dean, College of Engineering, Baton Rouge 3, La.

Apr. 1–2 **Sixth Annual Southern Municipal and Industrial Waste Conference,** North Carolina State College, Raleigh, N. C. Dr. Nelson L. Nemerow, Operating Committee Chairman, North Carolina State College, Raleigh, N. C.

Apr. 1–12 **Residential Course on Trade Wastes,** University of Durham, King's College, Newcastle upon Tyne, England. Peter C. G. Isaac, Senior Lecturer, Public Health Engineering, Dept. of Civil Engineering, University of Durham, King's College, Newcastle upon Tyne, England.

Apr. 4–5 **Eighth Annual Pacific Northwest Industrial Waste Conference,** State College of Washington, Pullman, Wash. William H. Knight, Technical Extension Services, State College of Washington, Pullman, Wash.

Apr. 15–19 **Rocky Mountain Water and Sewage Operations School,** University of Colorado, Boulder, Colo. Associate Professor Walter A. Weers, Dept. of Civil Engineering, University of Colorado, Boulder, Colo.

Apr. 24–26 **Sanitary Engineering Conference,** Manhattan College, New York, N. Y. Assistant Professor W. W. Eckenfelder, Jr., Civil Engineering Dept., Manhattan College, New York 71, N. Y. Conference subject, "Solids Handling and Anaerobic Digestion."

ACTIVITY OF CELLULOSE-DECOMPOSING FUNGI ISOLATED FROM SEWAGE-POLLUTED WATER

By Wm. Bridge Cooke and Kenneth A. Busch

Respectively, in charge, Fungus Studies, Microbiology, and Analytical Statistician, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

Sewage-polluted waters contain spores, other disseminules, and actively growing thalli of fungi capable of cellulose degradation. Maki (1) has shown that a large amount of cellulose is present in sewage, and that cellulose, both from this source and from such natural sources of pollution as decaying vegetation, is present in polluted waters. In general, cellulose deterioration in sewage is attributed to anaerobic cellulose-decomposing organisms in digesters. To determine whether or not fungi could attack cellulose in aerobic pure cultures and in competition with sewage organisms, experiments were devised in which strains of species of common molds were used both as spore inoculum and as mycelial inoculum in stationary liquid culture tests. Cotton cloth was used as the source of cellulose.

Experimental Technique

Two sets of studies were made. In the first study, the activities of 10 species of fungi, isolated infrequently to very commonly from sewage-polluted water, were compared singly and in four different mixtures. Specially prepared suspensions of mycelium and spores were used in the second set of studies.

Isolated Fungi Study

The cotton cloth was cut into appropriate lengths and stripped so that the tested material measured 1 in. by 3 in. The solution in which the cloth was incubated with the spore or cell suspension was a carbon-free medium of the following composition:

Item	Quantity (ml.)
Yeast extract (Difco) (1%)	10
NH_4NO_3 (10%)	10
$MgSO_4 \cdot 7H_2O$ (10%)	3
KH_2PO_4 (0.1M)	10
NaOH (0.1N) to give pH 6.1 to 6.3	2 to 4
Distilled water	1,000

Additions of 10 ml. of this solution were made to a 150-mm. by 15-mm. culture tube in which a cloth strip had been placed. Following autoclaving, 1 ml. of spore or mycelial suspension was pipetted onto the cloth, an aluminum cap was placed on the tube. The prepared tubes were stored in an incubator at 30°C. for 6, 9 and 14 days. Five strips were removed at the end of each period, washed, soaked 20 to 30 min. in 50 per cent ethyl alcohol, rinsed in water, and dried under moderate weight between pieces of absorbent material to prevent excessive curling. At the completion of the experiment these strips, together with 15 uninoculated control strips from each period, were tested for tensility on a Scott tensilometer. Results of the breaks were reported in pounds of tensile strength remaining in the strips.

Table I lists the species of fungi used in both the pure and mixed cultures in the first test, their frequency of occurrence in the polluted waters samples, and the approximate numbers of spores or mycelial fragments per milliliter of inoculum. The mixtures were chosen on the basis of their known inability to degrade cellulosic

TABLE I.—Effect of Fungi on the Tensile Strength of Cotton Duck Strips

Fungus		Natural Occurrence	Spores Per Ml. of Inoculum	Loss of Tensile Strength/ Days of Incubation (%)		
No.	Species			6 Days	9 Days	14 Days
1.	*Trichoderma viride*	Very common	45,000,000	60.3	88.3	93.0
2.	*Myrothecium verrucaria*	Infrequent	5,000*	74.3	89.6	94.0
3.	*Gliomastix convoluta*	Infrequent	250,000	0	2.6	10.3†
4.	*Penicillium lilacinum*	Very common	550,000	0	0.7	1.9†
5.	*Penicillium ochro-chloron*	Very common	3,000,000	44.9	73.1	84.4
6.	*Aspergillus fumigatus*	Common	5,000,000	58.6	80.5	92.8
7.	*Fusarium aquaeductuum*	Very common	150,000	17.3	0	72.8**
8.	*Cladosporium cladosporioides*	Common	250,000	3.8	1.6	0†
9.	*Geotrichum candidum*	Very common	17,600,000	0	1.4	2.6†
10.	*Pullularia pullulans*	Very common	12,000,000	0	3.7	0†
		Mixtures				
11.	4, 7, 9, 10	—	8,000,000	0	0	6.7†
12.	4, 5, 7, 9	—	2,800,000	0	2.1	0†
13.	1, 4, 5, 6, 7, 9	—	8,000,000	46.5	63.1	77.5
14.	All species	—	4,000,000	56.8	82.5	87.1

* Few spores produced, culture and inoculum mostly mycelial.
† According to previous work, values less than 15 per cent are of little significance.
** Values include strips contaminated with *Aspergillus fumigatus*.

materials (2), or as combinations of commonly isolated species.

Cultured Mycelium and Spore Study

In the second set of studies, two types of inoculum were used. The first type was a mycelium suspension developed by shaker culture and the second was a spore suspension developed on slants. The mycelial suspension was developed in a broth composed of 5 g. of phytone, 10 g. of dextrose, and 1,000 ml. of distilled water.

After autoclaving ten 100-ml. samples in 250-ml. Erlenmeyer flasks, the flasks were inoculated with spores or mycelium obtained from stock culture slants using an L-shaped needle. Then, the flasks were incubated at room temperature for three days on a rotary shaker at 150 oscillations per minute. After incubation the nutrient was filtered off through a membrane filter, the mycelial and spore material on the filter was washed and transferred to sterile distilled water in another Erlenmeyer flask, the filter was removed, and the mycelium was broken up in a Waring blendor operated at high speed for 30 seconds. This suspension was held in the refrigerator until used. Stock culture slants were prepared on phytone-dextrose agar slants, and the spores were scraped into 10 ml. of sterile distilled water by rubbing with a pipette. Spores from four slants were blended in a total of 100 ml. of sterile distilled water and used immediately.

Test procedures were identical with those used in the first set of experiments. Incubation periods of 6, 12, and 18 days were used. In addition to using the test medium described previously, 24-hr. settled domestic sewage and sterilized domestic sewage were used as incubation media. Settled domestic sewage could yield organisms which would compete with the fungi for the cellulose, whereas sterilized sewage could supply an added carbon source or nutrients which might speed up the cellulolytic activity of at least some strains of fungi used in the test. Test data are reported in Table II.

TABLE II.—Comparative Effect of Mycelium and Spore Inoculum on Tensile Strength of Cotton Duck Strips in Three Media

Fungus		Spores Per Ml. Inoculum		Remaining Tensile Strength/ Days of Incubation (%)					
				6 Days		12 Days		18 Days	
No.	Species	Mycelium	Spores	Mycelium	Spores	Mycelium	Spores	Mycelium	Spores
	(*a*) Test Medium								
0.	Control	—	—	100.0	100.0	101.9	112.4	97.0	104.2
1.	*Fusarium aquaeductuum*	840,000	150,000	100.7	103.0	101.1	112.4	98.0	115.3
2.	*Fusarium oxysporum*	820,000	125,000	94.1	91.8	53.6	96.0	65.1	98.9
3.	*Geotrichum candidum*	980,000	18,000,000	102.4	78.8	103.6	114.6	105.6	105.7
4.	*Penicillium lilacinum*	760,000	550,000	100.7	101.8	101.8	112.8	101.9	118.8
5.	*Penicillium ochro-chloron*	1,600,000	3,000,000	96.9	85.5	98.0	105.2	100.6	102.3
6.	*Pullularia pullulans*	—	12,000,000	—	96.1	—	116.2	—	109.5
7.	*Trichoderma viride*	4,000,000	45,000,000	99.1	101.8	102.0	116.4	100.9	112.7
8.	*Penicillium* (nr.) *melinii*	4,000,000	5,000,000	98.3	93.7	94.0	104.2	101.1	100.2
9.	*Margarinomyces heteromorphum*	1,400,000	1,500,000	100.2	104.0	96.7	99.7	101.0	109.3
10.	Average	—	—	99.1	95.2	93.9	108.6	96.8	108.1
	(*b*) Raw Sewage Settled 24 Hr. at 20° C.								
0.	Control	—	—	84.4	89.4	54.9	29.2	36.9	8.7
1.	*Fusarium aquaeductuum*	—	—	91.9	74.0	56.5	15.6	31.2	13.4
2.	*Fusarium oxysporum*	—	—	82.9	90.1	48.7	17.8	42.1	13.0
3.	*Geotrichum candidum*	—	—	93.6	80.0	62.7	11.7	41.4	14.5
4.	*Penicillium lilacinum*	—	—	93.4	78.3	63.7	29.2	35.9	12.7
5.	*Penicillium ochro-chloron*	—	—	91.0	91.8	62.7	4.5	43.4	15.3
6.	*Pullularia pullulans*	—	—	—	64.9	—	15.1	—	11.6
7.	*Trichoderma viride*	—	—	88.3	71.0	61.0	13.4	43.8	10.3
8.	*Penicillium* (nr.) *melinii*	—	—	87.2	73.6	57.9	15.4	34.3	3.7
9.	*Margarinomyces heteromorphum*	—	—	92.7	72.7	69.4	12.1	47.2	5.4
10.	Average	—	—	90.1	77.4	60.3	15.0	35.5	11.1
	(*c*) Raw Sewage Autoclaved 20 Min. at 15 P.S.I.								
0.	Control	—	—	102.1	107.9	100.2	98.7	102.7	112.4
1.	*Fusarium aquaeductuum*	—	—	98.9	103.8	94.1	111.4	101.1	109.8
2.	*Fusarium oxysporum*	—	—	95.9	96.4	87.5	95.9	85.5	106.3
3.	*Geotrichum candidum*	—	—	106.1	93.7	101.9	113.4	98.4	122.1
4.	*Penicillium lilacinum*	—	—	102.5	101.3	104.5	105.3	102.5	109.0
5.	*Penicillium ochro-chloron*	—	—	96.1	101.4	101.1	104.5	94.5	109.9
6.	*Pullularia pullulans*	—	—	—	100.4	—	102.8	—	110.5
7.	*Trichoderma viride*	—	—	94.1	100.4	96.9	106.7	94.8	105.2
8.	*Penicillium* (nr.) *melinii*	—	—	92.8	102.1	95.3	88.2	92.8	87.7
9.	*Margarinomyces heteromorphum*	—	—	98.5	100.4	97.4	104.2	91.8	103.2
10.	Average	—	—	98.1	100.0	97.3	103.6	95.2	107.1

Two series of fungal species were chosen for observation. In the first set of experiments, a miscellaneous group of species was chosen, strains of which were known to be actively cellulolytic. Certain commonly isolated species not previously shown to have any effect on cellulose were also

included. In the second study, the species of fungi most commonly isolated from sewage-polluted water were used.

Results

The results of the fungi, and mycelium and spore studies are given in Tables I and II, respectively. The ability of the fungi (Table I) to degrade cellulose materials, as shown by the tensile strength tests, differs from the results obtained by White *et al.* (2). ***Trichoderma viride***, ***Myrothecium verrucaria***, ***Aspergillus fumigatus***, and ***Penicillium ochro-chloron*** were very active, while the remaining species were either inactive or only slightly active. The strains of ***Gliomastix convoluta***, ***Cladosporium cladosporioides***, and ***Geotrichum candidum*** used showed no significant activity, although strains reported by White *et al.* (2) and by Siu (3) showed considerable activity. The inability of ***Pullularia pullulans*** to use cellulose is in agreement with the findings reported by White *et al.* (2). ***Penicillium lilacinum*** is listed by Siu (3) as being non-cellulolytic, while ***Fusarium aquaeductuum*** and ***Penicillium ochro-chloron*** had not been tested previously for such activity.

Fungus Combinations

The use of mixed cultures in testing cellulolytic activity apparently has been confined to fungal cultures whose activity is known (3)(4). In selecting a mixture of species for the first study, it was thought that a combination of fungi found in certain polluted habitats might also give a positive reaction. Combinations 11 and 12 (Table I), in which four of the most common species isolated from sewage were mixed, did not degrade cellulose. Apparently, in the presence of one or more of the three non-cellulolytic species used, the potential cellulolytic activity of ***Penicillium ochro-chloron*** could not be expressed. However, when two additional cellulolytic species were used as in Combination 13 (Table I), the three non-cellulolytic species did not exert this suppression. When all species were mixed together as in Combination 14 (Table I), little suppression was exerted, although the total activity was less than that exerted by any of the three cellulolytic species when used alone. ***Geotrichum candidum***, included in all mixtures and cited once by White *et al.* (2) as ***Oospora lactis***, is a highly variable species. Because of its great variability, including strains not known to be cellulolytic, its activity cannot be considered suppressed in Combinations 11 and 12.

Mycelium and Spores

The second study was made with seven species of fungi commonly isolated from sewage and polluted water (Nos. 1, 3, 4, 5, 6, 7, 9; Table II). One species of occasional occurrence but of potential interest because of its ability to utilize hydrocarbons as a sole carbon source (No. 2, Table II) and another species isolated repeatedly from streams carrying acid coal mine wastes (No. 8, Table II) were used without regard to previous assays. There is a possibility that one strain of a species may have different physiological requirements or activities than another. Two of the species under observation have been tested repeatedly by White *et al.* (2), the others only once, if at all. In reporting the results, only the groups of breaks averaging more than 15 per cent loss in tensile strength over the controls exposed for 6 days in the test medium were considered, although some breaks showing less than 15 per cent loss were found to be significant within the limits of these experiments.

Inocula

Preparation of inocula was independent of cellulose conditioning. In little, if any, of the work reported by White *et al.* (2) and by Reese and

Downing (5), is there mention of developing inocula using cellulose as a component of a culture medium designed to increase the yield of cellulose. Rather, it is emphasized that stock culture medium was potato dextrose agar with 2 per cent dextrose. In the first of the studies made, only a mycelium inoculum was used (Table II). Spores were present only in the case of those species which were able to produce spores in the liquid shaker culture. This capacity was most apparent in the cases of *Geotrichum candidum* and *Margarinomyces heteromorphum*. In only one test with the test medium and in one with the sterilized sewage did much cellulolytic activity take place. *Fusarium oxysporum* reduced the tensile strength of the cloth to 65.1 and 85.5 per cent of the control after 18 days of incubation in the test medium and sterilized sewage, respectively. On the average, the tensile strength of the cloth was reduced only 4 to 5 per cent by myecelial suspension inoculum after 18 days of incubation.

Siu (3) reported that when mycelial pads are used as inoculum the activity rate of a test fungus in the presence of a fungicide is more rapid than when spores are introduced as an inoculum. This may be caused by the inhibitory effect of the fungicide on spore germination, whereas the mycelium in the pad is already very active. On the other hand, if a young mycelium is washed and stored in a neutral solution it is possible that it is not producing sufficient enzyme to be effective in a stationary liquid culture (6).

In the test of spores in the second study (Table II), a rather heavy spore suspension was prepared as inoculum. It was expected that at least *Trichoderma viride* and *Penicillium ochrochloron* would reproduce the earlier results, but in both the test medium and the sterile sewage there was an increase in tensile strength of the cloth during the 18-day incubation period.

There was a marked reduction in tensile strength of the cloth, using raw sewage which had settled 24 hr. in a 20° C. constant temperature chamber. The strength was reduced slightly less when mycelial suspensions rather than spore suspensions were used. The contents of raw sewage, of which samples were obtained several months apart for the two tests, were extremely variable from day to day and from hour to hour. However, this did not seem to account for the greater loss of tensile strength when spore inocula were used, although some fungal species are known not to degrade cellulose. It is possible that none of the fungi inoculated on the strips of cloth had cellulolytic effect, since organisms which carry on degradation may have been present in the raw sewage.

Statistical Analysis

A statistical anlysis was made of the data in the second study. The experiment was treated as a factorial design with four factors:

1. Length of treatment or "time" (T) at three levels; 6, 12 and 18 days.
2. Inoculum (I) of two types, mycelium and spores.
3. Medium (Mm), of three types; mineral salts, raw sewage, and sterilized sewage.
4. Mold (Md) of which there were 9 species, one control and eight experimental. Mold 6, Table II, was not included in these analyses.

There existed $3 \times 2 \times 3 \times 9$ or 162 combinations of the various levels of these factors, 144 of which were replicated five times and the remaining 18 were replicated 15 times. There were 990 individual measurements taken. The variable used was pounds of tensile strength required to break the test strips as measured with a Scott tensilometer.

Results of a preliminary four-factor analysis of the data involving the

TABLE III.—Four-Factor Experiment, Controls Omitted

No.	Source of Variation	Degrees of Freedom	Estimate of Variance	"F" Ratio
1	Medium (Mm)	2	705,133	(1)/(6) = 7.18*
2	Mold (Md)	7	4,616	(2)/(9) = 2.37
3	Time (T)	2	68,619	(3)/(6) = .70
4	Inoculum (I)	1	20,775	(4)/(19) = .77
5	Mm × Md	14	1,698	(5)/(17) = 2.98†
6	Mm × T	4	98,266	(6)/(14) = 8.13*
7	Mm × I	2	81,391	(7)/(14) = 6.73
8	Md × T	14	802	(8)/(17) = 1.41
9	Md × I	7	1,944	(9)/(17) = 3.41†
10	T × I	2	2,364	(10)/(14) = .39
11	Mm × Md × T	28	523	(11)/(15) = 1.06
12	Mm × Md × I	14	786	(12)/(15) = 1.60
13	Md × T × I	14	607	(13)/(15) = 1.24
14	Mm × T × I	4	12,093	(14)/(15) = 24.60†
15	Mm × Md × T × I	28	492	(15)/(16) = 1.59*
16	Residual	567	309	—
17	Pool (11), (12), (13) and (15)	84	570	—
18	Pool (17) and (8)	98	603	—
19	Pool (14), (7) and (10)	8	26,985	—

* Significant at 5 per cent probability level.
† Significant at 1 per cent probability level.

eight fungi, exclusive of the controls, are presented in Table III. The computations of the variance components were performed by the usual methods for a complete factorial experiment. The large medium main effect was caused by the breaking strength values for strips exposed in the raw sewage medium which were about one-half the values obtained from strips exposed in the other two media.

A three-factor analysis was then made for each of the three media used, but it was found that for a given medium the magnitude of the difference between inocula depended on the length of treatment. Therefore, two-factor (I and Md) analyses were made for each length of treatment for each medium.

Three types of results were obtained from these two-factor analyses. Of these, the most important result was that there was no interaction between inoculum and mold. That is, the difference between inocula was the same for each mold tested for a given length of treatment. Each of the three raw sewage experiments gave similar results. The strips from the spore inoculum had one-fourth to one-fifth the breaking strength of those from the mycelial inoculum after 18 days of incubation.

In comparing a mold with its control strips for both kinds of inocula, and for a given length of treatment and given medium, eight types of results were found, most of which were based on rather minor variations in the over-all picture of significant cellulolytic action by the experimental mold. *Geotrichum candidum*, *Fusarium oxysporum* and *Penicillium* (nr.) *melinii* gave some appreciable cellulolytic activity. In this analysis, values were based on pounds of tensile strength lost rather than on a comparison of percentage losses. In the test medium, spore inocula were more active after six days than mycelial inocula in the case of *Geotrichum candidum*, whereas mycelial inocula of *Fusarium oxysporum* were more active after 12 and 18 days of incubation. In raw sewage, combined values for spore inocula of all the molds used gave

lower values at each harvest period than mycelial inocula. In sterilized sewage, at the end of six days, a mycelial inoculum of *Geotrichum candidum* showed some activity, whereas at the end of 18 days a mycelial inoculum of *Fusarium oxysporum* and a spore inoculum of *Penicillium* (nr.) *melinii* showed appreciable increases in activity.

Six two-factor analyses, comparing lengths of treatment and different molds for a given medium and a given inoculum, were studied so that changes in breaking strength with variation in incubation time could be observed. No changes significant for demonstrating cellulolytic activity of fungi were found.

Discussion

In sewage-polluted waters such as those from which the fungi under consideration were obtained, there may be many carbohydrates present. Some of these may be simple pentoses or hexoses which would be degradation products of sewage solids not available for use by the organism through whose action they were produced. Maki (1) has shown that glucose is a metabolic by-product formed by one group of cellulolytic bacteria which cannot use it in its metabolism. While such substances may be present in dilute solution, they are usually in sufficient quantity to help in maintaining a population of microorganisms capable of using them as food. Such microorganisms include those filamentous fungi under consideration in this study.

Certain fungi have been shown (2) to be able to use cellulose at least in pure culture. In one series of experiments, strains of fungi found more commonly in sewage-polluted water were shown to be able to use cellulose in pure culture. It seems possible, then, that these fungi may be able to use cellulose as a food substrate in sewage-polluted waters where cellulose is present in large amounts.

When the more common species of fungi isolated from sewage-polluted waters are tested in mixed culture, the cellulolytic activity of certain species appears to be reduced. Mixtures of species containing certain strains known not to use cellulose give no loss of tensile strength of test cloth strips, while mixtures containing strains of species known to use cellulose showed less loss of tensile strength than when the known users were tested in pure culture.

Following a test of eight commonly occurring sewage fungi on cotton cloth, it was found that in a mineral salts solution little activity occurred except for strains of two species known to be cellulolytic. There was no increase in activity when sterilized sewage was used. In the case of raw sewage, the amount of cellulolytic activity in general was correlated with the sewage rather than the fungi since there was no significant difference between the species of fungi used. Because washed mycelial inoculum was used, it was possible that insufficient amounts of cellulase were being produced by this type of inoculum. In a second test, spore suspensions rather than mycelial suspensions were used. The purpose of the test was to determine whether germinating spores and young mycelium, which had not previously been washed, would be better producers of cellulase than washed mycelium. The principal difference between the two experiments was a uniformly better action of the spore inoculum in raw sewage. Except for a slightly increased tensility of the cloth in mineral salts and sterile sewage media, no other effects were noted.

Statistical analyses of the second half of this experiment gave little indication that one fungus was better than another in this type of activity.

Two possible explanations for this lack of cellulolytic activity are based on data from the second set of experiments. First, the cellulase-producing

capacity of the test organisms was reduced during two to three years of storage in the laboratory on media containing no more complex carbohydrates than glucose. Second, populations present in the sewage which could utilize cellulose were encouraged to increase through the release of by-products of fungal inoculum activity and the removal of toxic materials by other organisms present in the complex population.

Summary and Conclusions

Fungi capable of using cellulose as a sole carbon source are present in sewage-polluted waters.

Inocula of fungus mycelia are less effective in aiding the reduction of cellulose than inocula of spore suspensions when the growth medium is raw sewage. For the other media, spore suspension inocula are somewhat less effective. This may be related to the conditioning of the inocula.

Raw settled sewage appears to contain organisms capable of utilizing cellulose as a carbon source in the presence of other organisms which may remove toxic substances and/or provide growth promoting substances.

Acknowledgment

The authors acknowledge the courtesy of Dr. Elwyn T. Reese, Pioneering Research Laboratory, U. S. Army Quartermaster Research and Development Laboratories, Natick, Mass., in obtaining and breaking the cotton cloth used in the studies reported.

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CORRECTIONS

In the paper on "A Colorimetric Method for Determining Dissolved Oxygen," by Charles S. Oulman and E. Robert Baumann (THIS JOURNAL, **28**, 12, 1461; Dec., 1956), the following corrections should be made:

1. In Eq. 1 on page 1463, the equals sign (=) in front of log. 100 should be a plus sign (+).
2. In the fifth line above Eq. 1, the word "oxidation" should read "reduction."

Special acknowledgment is due Clifford Hach of the Hach Chemical Company, Ames, Iowa, who made valuable contributions to the study through the furnishing of equipment, supplies, and suggestions in the execution of this project.

In the paper on "Pollution Reduction Program for the Textile Industry," by Joseph W. Masselli and Gilbert Burford (THIS JOURNAL, **28**, 10, 1273; Oct., 1956), the name of the junior author should read, "M. Gilbert Burford."

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

OPERATOR'S CERTIFICATION PROGRESS

A Report of the Operator's Qualifications Committee *

The present Committee has reviewed the 1945 report "Qualifications of Sewage Treatment Plant Operators" (1) in light of experience of the past 11 years and herewith presents its opinions on the subject.

The trend towards a means of recognizing operator qualifications through certification continues at a rapid rate. The first plan of this type was developed in 1919 when New Jersey required licenses for sewage plant operators. In the decade 1930–39 nine plans were inaugurated (three of them required by law); during 1940–49 four more were begun and the period 1950–56 has seen 11 additional plans developed. At present there are 25 states using some type of certification or licensing plan (Table I).

It is most interesting to note that there are now seven plans requiring sewage plant operator certification or licensing by law. Four of these were developed without first having functioned as voluntary programs (New Jersey, Connecticut, New York and Ohio). The other three originated as voluntary plans before reaching legal status (Texas, Illinois, and Michigan). Thus it is noted that 21 of the 25 plans now in effect, or 84 per cent, began or continue as voluntary programs.

This Committee has no basic disagreement with the 1945 report. It does wish to point out that while it is desirable that "State regulations on qualifications of plant operators should be compulsory—not voluntary," as is stated in the 1945 report, the fact is that 72 per cent of the existing plans are voluntary. It is understood that several states such as Indiana, Iowa, and Michigan have attempted to obtain legislation on the subject without success, and the latter two states began voluntary programs in 1952. During the last four years, 1952–56, 11 voluntary programs were begun.

There are now three states which certify only sewage plant personnel (Iowa, Washington and Wisconsin), while four of the 26 states certifying water works operators do not have a plan for the sewage works operators (Tennessee, Kentucky, West Virginia and Oregon).

Among the voluntary sewage plans only three states (Florida, North Carolina and Oklahoma) have the certificates issued by the state health authority, while in Minnesota the program is conducted entirely by the health department. The other 14 states operate through a certification board appointed by the local sewage association which issues the certificates. This would seem the better method in the initial stages of a program.

Scope of Certification Plans

Most of the plans encourage operators to advance their knowledge and ability by certifying practically everyone engaged in sewage plant operations, although some limit certification to supervisory personnel. It is believed to be better to certify as many

* Presented to the 1956 Federation Board of Control; Los Angeles, Calif.; Oct. 7, 1956.

TABLE I.—Sewage Plant Operator Certification Plans

State	Year Began	
	Voluntary	Mandatory
New Jersey	—	1919
Connecticut	—	1933
South Carolina	1935	—
Georgia	1936	—
California	1937	—
New York	—	1937
North Dakota	1937	—
Ohio	—	1937
Texas	1938	1945
Illinois	1939	1952
Michigan	1940	1952
Florida	1941	—
Louisiana	1947	—
Oklahoma	1949	—
Alabama	1952	—
Arkansas	1952	—
Iowa	1952	—
Minnesota	1952	—
Missouri	1953	—
Washington	1953	—
North Carolina	1954	—
Pennsylvania	1954	—
South Dakota	1954	—
Wisconsin	1956	—
Kansas	1956	—

operators as possible rather than limit certification to the supervisory group. Since the purpose of any such program is to encourage better operation of plants, certification ultimately should include those who are intimately concerned with the physical operation of the plant.

In Louisiana, North Carolina, and North Dakota sewage plants are classified by type of treatment and the operator classifications are made accordingly. In California and Georgia the class of certificate issued depends on the experience and training of the applicant and does not limit him to a class of certificate applicable only to the plant in which he may be working at the time of certification. The other 13 voluntary plans base the class of certificate on both the type of treatment and the population or flow for which the plant may be designed. It is believed that classification of personnel based on the individual's training and experience is best since it does not limit an operator to a specific type of plant in which he may at the moment be working.

Conclusions

The effectiveness in promoting or developing any certification plan depends on the cooperation of all groups who may be concerned with the plan. It seems advisable to consider a joint approach by enlisting the assistance of the local water works group, usually the local section of the American Water Works Association, and when available the local municipal league. The latter offers the aid of the employer and can lend valuable assistance in making any plan function properly. There is only a slight difference in the plans for water and sewage operators and the fact that 10 states have developed both water and sewage plans at practically the same time would support the cooperative effort approach.

It seems reasonable to believe that initiation of any certification plan on a voluntary basis offers the best chance of success. The effectiveness of such a plan provides proof of its value when requesting legislative action to make it a mandatory one.

The Committee therefore recommends that in those states where no plans now exist the Member Associations of the Federation give serious thought and study to developing voluntary plans as a first step toward mandatory certification of sewage plant operators.

Acknowledgment

The Committee chairman (W. McLean Bingley) is most appreciative of the constructive comments and assistance of Committee members, W. T. Ballard, Benjamin Benas, T. C. Schaetzle and Sol Seid.

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1. Van Kleeck, L. W., Allen, W. A., and Molitor, E. P., "Qualifications of Sewage Treatment Plant Operators." *Sewage Works Jour.*, **18**, 1, 147 (Jan., 1946).

PUBLIC HEALTH SERVICE PROGRAMS OF INTEREST TO SEWAGE TREATMENT PLANT OPERATORS *

By Bernard B. Berger

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Organization of Engineering Services

The Public Health Service programs of most direct interest to sewage treatment plant operators are part of the USPHS engineering operations. The work of the Water Supply and Water Pollution Control Branch of the Public Health Service and the Robert A. Taft Sanitary Engineering Center at Cincinati, Ohio, is closest to the problems and interests of sewage treatment plant operators. The Sanitary Engineering Center, in particular, with its emphasis on research, technical assistance, and training, is concerned with the technical problems of the operators. Because much of what is to be discussed in this paper will be based on the work of the Center, a description of its organization is given in Figure 1.

The operating units of the Sanitary Engineering Center are identified with the major phases of environmental health and, in this respect, they parallel the branches of the Division of Sanitary Engineering Services. This reflects the Center's fundamental function, which is to serve as the technical arm and research hub of the USPHS sanitary engineering programs.

Programs of greatest interest to sewage treatment plant operators are those of the Water Supply and Water Pollution Program and the Training Program. The Radiological Health Program, which was just recently established as a separate unit, may be expected to expand its activities into areas of increasing importance to sewage treatment plant operators.

To understand the phases of the Water Supply and Water Pollution Program it is necessary to know the administrative framework in which the work involving the states and municipalities is conducted. Over the years, the Public Health Service has developed a close working arrangement with the state health departments. This relationship is based on the primary responsibility of the states in intrastate matters involving public health. Public Health Service resources such as personnel and facilities are always available to the states in emergencies or where unusual or difficult problems are encountered, but they are used only if the state feels it necessary to do so. Ordinarily, Public Health Service personnel would not conduct studies at municipal waterworks or sewage treatment plants without the prior request of, or arrangement with, the state health authorities. This traditional working arrangement is a basic characteristic of Public Health Service-state relationships.

To facilitate conduct of Public Health Service-state programs, the Public Health Service has decentralized its authority and operations into eight regional offices covering the United States and its territories. All programs involving the states, including the work of the Division of Sanitary Engineering Services and its component units, are carried on through these offices. Public Health Service regional engineers and their staffs are in close touch with the states and, at state request, are ready to assist on sewage treatment problems as well as on other important environmental health problems.

* Presented at the 1956 Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Los Angeles, Calif.; Oct. 8–11, 1956.

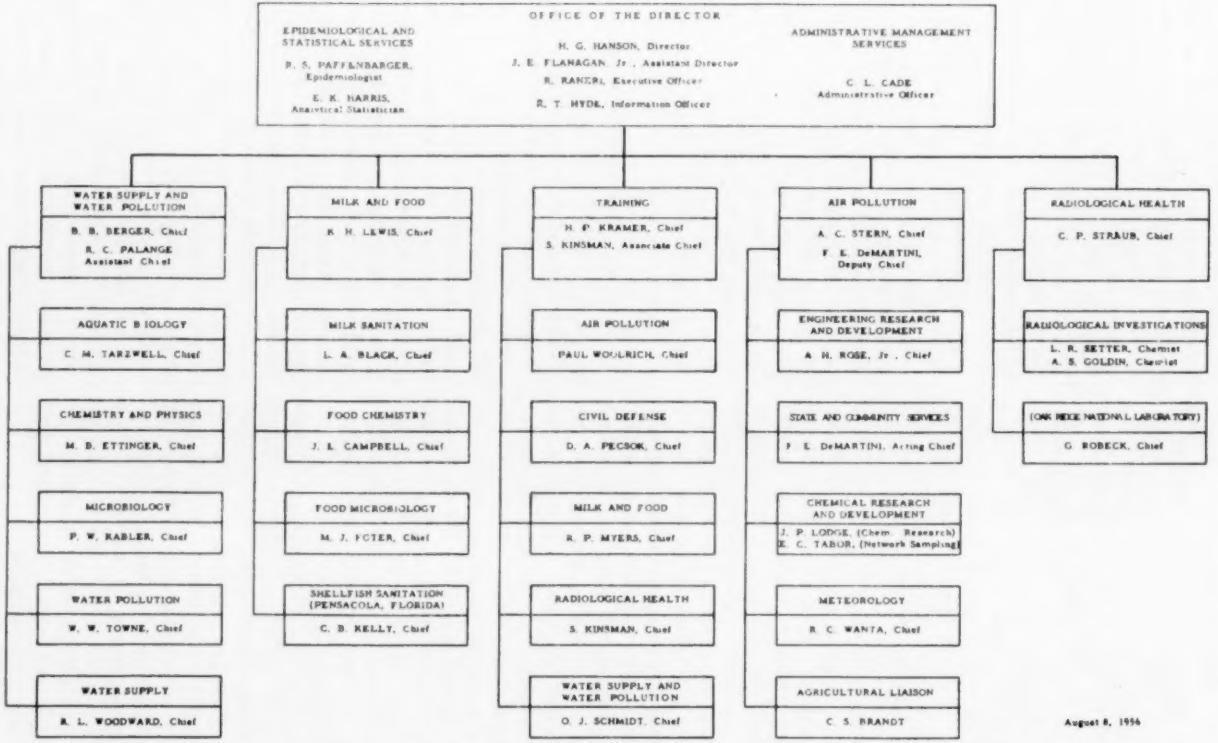

FIGURE 1.—Tentative organization of the Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio.

Water Supply and Water Pollution Control Branch

This component of the Division of Sanitary Engineering Services is responsible for the over-all operation of the water supply, water pollution, and water resources programs of the Public Health Service. Its primary task in water pollution is the administration of the Water Pollution Control Act, Public Law 660, recently enacted by the 84th Congress. Activities of interest to sewage treatment plant operators include the following:

1. Development of comprehensive pollution control programs for interstate waters. This activity is carried on cooperatively with other federal agencies and with state and interstate water pollution control agencies. The Public Health Service is required to consider all legitimate water uses in the development of the comprehensive program, including the use of waters for public water supplies, fish and wildlife, recreation, agriculture, industry, and other uses. Therefore, the Public Health Service interest in water pollution extends beyond the effects of pollution on public health.

2. Administration of the construction grant provision of Public Law 660. This program will be handled by the Water Supply and Water Pollution Control Branch and the regional offices.

3. Collection and analysis of basic data on the effects of water pollution control on regional economic development. The far-reaching benefits that may result from control of pollution can be measured only imperfectly. Much additional information is needed for the guidance of water pollution control programs and for making reliable predictions of the regional economic advancement that a control program may make possible.

Regional Offices

The basic mission of the regional offices is to assist the states in determining their public health and related needs, to bring Public Health Service resources to bear on these needs, and to administer the programs dealing with the states and their subdivisions. In line with these functions, all direct operations of Public Health Service elements relating to water pollution control are provided through the regional offices. In addition, the regional offices assist the states through the use of their own engineering skills and allied resources. It would not be possible to list all the ways in which assistance may be rendered. Many special studies are carried out by the regional offices, which in one way or another are related to the operations of sewage treatment works.

Contact with the Robert A. Taft Sanitary Engineering Center, or with any other Public Health Service program, will normally be made through the regional offices of the Department of Health, Education and Welfare.

Sanitary Engineering Center Research Program

The Sanitary Engineering Center scientific staff in water supply and water pollution research numbers about 60, and includes specialists in engineering, epidemiology, toxicology, chemistry, physics, microbiology, aquatic biology, and statistics. An equal number of employees is included in the supporting staff. Many of the projects on which the specialists are engaged, should be of interest to sewage treatment plant operators.

The projects described below chiefly relate to research on sewage. The program in water supply and water pollution places considerable additional emphasis on the problems of industrial wastes and water quality, and on the increasingly important problems of water conservation. In accordance with the provisions of the Water Pollution Control Act and the recommendations of the President's Advisory Committee on Water Resources, there is being developed a national plan for collection and interpretation of basic data on water quality related

to pollution. As part of the over-all basic data program, it is proposed to publish a national inventory of municipal and industrial waste facilities in 1957.

Permissible Coliform Organism Loadings on Water Treatment Processes

The coliform organism concentrations for water treatment plants were first recommended by the Public Health Service approximately a generation ago. For raw water, subjected to conventional treatment consisting of chemical coagulation, settling, rapid sand filtration and post-chlorination, the recommended allowable loading is 5,000 coliform organisms per 100 ml. of water. This recommendation has been widely used by state health departments, and it is still being used in many locations.

In view of the improvement in water treatment practice in recent years, the Sanitary Engineering Center considered it timely, approximately two years ago, to review the validity of this recommendation. Accordingly, studies on treatment efficiency have been made at approximately 60 municipal water treatment plants receiving waters containing coliform organism concentrations consistently far in excess of the recommended limit. The study shows that with the present methods of coagulation control and, particularly, with improved chlorination practices, water treatment plants may produce drinking water of acceptable bacterial quality from raw water much more heavily contaminated with coliform organisms than was previously considered practicable.

Significance of Viruses in Water

Many pathogenic viruses discharged in human feces may remain viable in water for long periods of time. Among these viruses are the polio virus, the coxsackie virus, and the virus of infectious hepatitis. Epidemiological evidence does not point to contaminated water as the vehicle of transmission for poliomyelitis and the diseases caused by the coxsackie viruses, despite the fact that these organisms frequently may be recovered from sewage. However, the water route has definitely been implicated in the transmission of infectious hepatitis.

The most spectacular outbreak of this disease attributed to contaminated raw water was the occurrence of more than 7,000 cases in the winter of 1955–56 in New Delhi, India. This outbreak is the only case where a completely treated water has been incriminated in the spread of this disease. Although the operating efficiency of the New Delhi plant may be debated, an important question has been raised concerning the ability of any conventional water treatment plant to remove completely pathogenic virus when it is present in the raw water in a heavy concentration.

The Sanitary Engineering Center has been concentrating on the development of practical procedures to permit the evaluation of the virus hazard in drinking water. The problems have been two-fold. First, the tools for recovering, identifying, and counting the viruses in highly dilute suspension have not been available. Second, to date the virus of infectious hepatitis has been grown only in the living human body, and consequently work on this virus requires a suitable culture procedure.

Procedures are being developed for the recovery of viruses suspended in low concentrations. One of the pharmaceutical houses has recently reported the successful development of a tissue culture technique for growing viruses from clinical cases of infectious hepatitis. Intensive work is being conducted in the confirmation of this procedure.

Significance of Fungi in Water

The significance of fungi in sewage and contaminated waters has not been adequately evaluated. Until several years ago, not much work had been done to determine their importance in

the water phase of the environment. At that time, the Sanitary Engineering Center undertook to determine the kinds of fungi favoring polluted water environments and their possible significance. Accordingly, studies have been conducted of the biological sewage treatment processes and polluted streams.

Several interesting observations have been made. Among these are the role of fungi in the stabilization of sewage solids and their adaptation to polluted environments. Certain species of fungi have been found to be strongly competitive with bacteria in the use of sewage solids as their nutrient material, and under certain conditions, such as at low pH, fungi may exceed bacteria in their ability to utilize such materials. A further observation that may be of interest to agricultural agencies is the identification of a fungal species commonly found in sewage effluents as one which under other circumstances may be associated with plant disease. The significance of this observation remains to be determined.

Improvement in Bacteriological Water Examination

The use of the membrane filter technique for rapidly and reliably estimating the concentration of coliform organisms in a sample of water is now well known. The Sanitary Engineering Center is currently evaluating a delayed incubation procedure which will permit mail shipment of the membrane filter sample to laboratories and an enumeration of coliforms after 24 to 48 hr. in transit. There are 14 municipal water supply systems participating in this evaluation.

Effect of Industrial Waste Components

The Sanitary Engineering Center has just recently begun a study of the effects of heavy metals on the biological sewage treatment processes. This study is being conducted because many requests have been received for information and technical assistance. A critical review of the literature is being completed, and laboratory studies on selected metals are soon to be initiated.

Dissolved Oxygen Recorder

The need for an automatic, continuously recording, dissolved oxygen analyzer has been recognized for many years, and many agencies have worked on the development of such an instrument. The Sanitary Engineering Center, perhaps more than most agencies, has felt the need for this device because of its extensive studies on stream pollution. After several years of work, it is believed that development of the dissolved oxygen analyzer is approaching a conclusion. A prototype of an instrument suitable for use in stream pollution studies soon will be tested under representative field conditions.

Effect of Water Resource Developments

Impoundments and other river developments may produce adverse effects on water quality and on stream self-purification. Studies are being conducted on the evaluation and control of several important problems resulting from river development. Present investigations include:

1. The extent of dissolved oxygen depletion produced by withdrawals from the deeper strata of impoundments.
2. The effect on stream self-purification produced by the construction of navigation dams which change free flows to navigation pools.
3. The effect on stream self-purification produced by changing stream flow patterns resulting from intermittent operation of hydroelectric power generation plants.

Each of these factors may influence existing as well as new sewage treatment requirements. Their evaluation

is essential to proper engineering design and to plant operation.

Development of New and Improved Sewage Treatment Processes

The Sanitary Engineering Center is conducting studies on several processes which seek to provide sewage treatment at lower treatment cost, particularly for small communities. These processes are the waste stabilization pond, the anaerobic reduction process, and the use of novel oxidative surfaces.

The waste stabilization pond is generally recognized as a cheap, effective means of complete sewage treatment, but its use has been retarded because of uncertainty as to acceptable design criteria. The establishment of suitable design criteria awaits review of operational experience, coupled with added information on the physical, chemical, and biological phenomena involved in the stabilization process. Cooperative studies with the health agencies of North and South Dakota recently have been completed on lagoons in these states under representative meteorological and seasonal conditions. Studies on experimental units in other states have been initiated.

The development of an anaerobic reduction process for the treatment of sewage was initiated approximately a year ago. The laboratory studies have been completed and the work is now in the pilot-plant phase. This simple process may provide a relatively high degree of stabilization, producing an effluent comparable to that from conventional secondary treatment.

A study has been undertaken in cooperation with the City of Battle Creek, Mich., the Michigan State Health Department, the Michigan Water Resources Commission, and the Dow Chemical Company on a pilot-plant evaluation of a 40-ft. oxidation tower utilizing a polystyrene oxidative surface. Departures from conventional trickling filter design, by using new materials which provide high surface area to volume ratios and high porosities, offer attractive opportunities for research in the treatment of domestic and industrial wastes. The arrangement of such materials in tower-like structures may make possible modification of trickling filter design practice. The Sanitary Engineering Center proposes to pursue studies on oxidation, utilizing a variety of materials and surfaces in a pilot plant in Cincinnati.

Research on water quality and sewage treatment will be facilitated by large pilot plants now being constructed in the Cincinnati laboratories.

Sanitary Engineering Center Technical Services

An active technical assistance program is maintained to assist the states and municipalities on problems of water pollution requiring resources not available locally. Every professional member of the Sanitary Engineering Center, and this comprises the whole spectrum of specialties that can be brought to bear on research problems, is available as a consultant on problems falling within his field of competency. A large portion of the time of the staff is actually devoted to this service. For technical services requiring field work, there is a staff of engineers, chemists, and biologists, who can be equipped as teams to go into the field for extended periods of time. Such field studies are expensive, and it is necessary to apply fairly strict screening criteria before committing resources to them.

Among the field investigations conducted during 1955–56 were the following:

1. Study of the Columbia River to define major factors contributing to the growth of sphaerotilus interfering with commercial fishing industries.

2. Study of French Creek, Pa., to determine the probable effects of proposed multiple purpose reservoirs on existing water supplies and on municipal and industrial waste discharges.

3. Study of the Snake and Green

rivers in Idaho to assist the United States Forest Service in a study of the water supply requirements for timber resources development, including stream flow requirements for assimilation of waste products.

4. Study of Yellowstone River to evaluate the effects of beet sugar wastes in Montana on downstream water uses in Montana and North Dakota.

These investigations merely illustrate the problems studied in the field at the request of the several state water pollution control agencies. Although most of the work in the past has been directly concerned with the stream itself, it would be possible, as part of the technical services program, to send teams of investigators to supplement local efforts on other important problems.

Sanitary Engineering Center Training Program

The training program provides short, intensive courses designed to bring the latest and best available research findings to practicing professional workers in the field of sanitary engineering. Lectures are supplemented by laboratory and field demonstrations so that the transfer of new knowledge from research to practical application may be made most effective. The research staff participates in these training programs.

In the fiscal year beginning July 1, 1956, 9 training courses in water supply and water pollution are planned in Cincinnati, and 14 courses are planned for the field. Field courses are specially prepared at the request of a state to assist in providing advanced training to its staff. In addition to serving the technical purpose of the courses, the field program is designed to aid the state in the development of its own advanced training courses in water supply and water pollution.

In addition to the courses on water supply and water pollution, basic and advanced courses are conducted in radiological health training. Among the courses specifically directed to professional workers in the water phase of the environment, are the following:

1. Basic radiological health, 2 weeks.
2. Environmental radiation sanitation, 2 weeks.
3. Problems of radioactivity in waterworks, 2 weeks.

There is no charge for the courses given by the Sanitary Engineering Center. They are given primarily for employees of state and municipal health departments and similar agencies. Properly qualified individuals from industries and universities participate in the courses. Sewage works employees with professional background are eligible.

The demand for attendance at the Sanitary Engineering Center training courses has been great and is still growing. In the past year, approximately 800 engineers, chemists, and other scientists participated in water supply and water pollution courses. The limited facilities have been taxed to the utmost to take care of those who have desired this training. Perhaps relatively few sewage treatment plant operators have attended these courses, either in Cincinnati or in the field, considering the number of qualified persons who might well take advantage of this training.

The training courses are not static. At any particular time they represent the latest and most useful knowledge available to those working in the general fields of interest. Those in charge of this program are alert to the needs of professional workers in the sanitary fields. They, as well as the research staffs, try constantly to be responsive to these needs in research and in training.

Conclusion

The Public Health Service desires that sewage treatment plant personnel consider the technical services, research, and training programs as a resource available on whatever important problems may be encountered where help is needed.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"When a man does only what he must do, he will remain all his life in the rank and file."—*Anon.*

Attention operators! It will be appreciated if copies of all annual reports of both large and small sewage and industrial waste treatment plants are sent to the Federation office for abstracting in this section of the Journal. Please direct annual reports to: The Operator's Corner, Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D.C.

Annual Report of the Fond du Lac, Wis., Sewage Treatment Plant for 1955 *

By C. W. Bogenhagen, *Superintendent*

The Fond du Lac, Wis., sewage treatment plant has undergone a series of modifications and improvements since construction of an Imhoff tank in the early 1900's. The original Imhoff tank plant served with modifications until the early 1920's, when a primary-type plant with separate sludge digester was constructed. About then a large tannery constructed a 20-in. force main to discharge its waste directly to the plant.

Continued industrial growth resulted in an overload condition and required improvements to the plant. These additions were inadequate and in 1948–50 a new secondary-type treatment plant was constructed. Some units of the old plant were remodeled. The new plant has trickling filters and vacuum sludge drying facilities. A 90-ton incinerator for garbage and rubbish was incorporated into the revised plant.

The current construction program includes a 1,000-ft. extension of the 32-in. outfall sewer into the lake and a 100-kw. gas-engine generator unit. The latter will utilize the digester gas now wasted. The engine cooling water will be used to maintain satisfactory digester temperatures.

Total precipitation was 20 per cent less than in 1954. Average flow to the plant has shown little variation in recent years. The tannery contributes approximately 25 per cent of the total flow; domestic flow, 3.08 m.g.d., and tannery flow, 1.03 m.g.d.

Digester foaming occurred in May and July. Gas production increased by fall as digester temperatures were increased. Tannery wastes aided in producing an average of 1.96 cu. ft. of gas per capita. A total of more than 22 million cubic feet of gas was produced, and 4.73 million cubic feet were wasted.

A new chain was installed on the tannery screen building elevator. Old lift station pumps and motors were removed. Sludge beds were rebuilt in May. The new gas-engine generator set was given several test runs. Difficulties were experienced with the water-cooling system and generator electric panel.

A complete year of laboratory data on tests of the lake and river water for coliform organisms was recorded. A new employee relationship ordinance was adopted for city employees.

Capital outlays for equipment, including storm-water pumps, repairs to sludge beds, and experimental chlorination, amounted to $19,165.35. Sales of dried sludge totaled $4,079.30. Operating data are summarized in Table I.

* For last previous extract see This Journal, **26**, 7, 919 (July 1954).

TABLE I.—Summary of 1955 Operating Data for the Fond du Lac, Wis., Sewage Treatment Plant

Item	Average
Population served	31,500
Population equiv.	41,000
Rainfall (in.)	23.13
Sewage flow treated (m.g.d.):	
Total	4.02
Domestic	3.08
Tannery [1]	1.03
Per capita (g.p.d.)	128
Screenings, tannery:	
Total (cu. yd.)	241
Per m.g. (cu. yd.)	0.28
Grit:	
Total (cu. yd.)	215
Per m.g. (cu. yd.)	0.19
Solids (%)	42
Volatile (%)	48
Settleable solids (ml./l.):	
Domestic	10
Tannery	19
Combined	13.5
Effluent	0.17
Reduction (%)	99
Suspended solids (p.p.m.):	
Domestic	685
Tannery	746
Combined	595
Effluent	34
Reduction (%)	94
B.O.D., 5-day (p.p.m.):	
Domestic	191
Tannery	349
Combined	205
Effluent	33
Reduction (%)	84
pH:	
Domestic	7.1
Tannery	9.3
Combined	8.1
Effluent	7.6
Raw sludge	7.3
Gas prod.:	
Total (mil. cu. ft.)	22.62
Waste (mil. cu. ft.)	4.73
Per capita (cu. ft./day)	1.96
Per m.g. sewage (cu. ft.)	15,450
Vacuum filters:	
Run monthly (hr.)	888 [2]
Run per work day (hr.)	18
Rate (lb./hr.)	816
Sludge filtered, total (m.g.)	6.16
Solids (%)	8.7
Cake moisture (%)	68
Dry solids (tons)	2,144.5
Dry solids (%)	86
CaO, total (tons)	392
$FeCl_3$, total (tons)	81
Fuel oil used, total (gal.)	85,635
Operating costs ($):	
Total	118,239.21
Per capita	3.76
Per mil. gal.	79.50

[1] Based on 330 days.
[2] Total for two filters 6 ft. by 8 ft.

Annual Report of the Jackson, Mich., Sewage Treatment Plant for the Fiscal Year Ending June 30, 1955 *

By R. A. Greene, *Superintendent*

The sewage treatment plant experienced normal operation without a single interruption and satisfactorily treated all of the sewage reaching the plant. The average daily flow of 10.15 m.g.d. was the highest flow in 18 years of operation and represented an increase of 1.06 m.g.d. over 1954. The rate of flow ranged between 10 m.g.d. and 15 m.g.d.; the design flow of this activated sludge plant is 11.15 m.g.d. Most of the increase in sewage flow can be attributed to an increase in domestic and industrial water use, particularly industrial. Suspended solids and B.O.D. concentrations were slightly lower, but treatment efficiency was on a par with previous years.

The sewage treatment plant operates as a utility, paying for treatment plant operation, pump station maintenance, sewer maintenance, interest on its bonded debt, and a portion of the administration cost of the city. In addition, a sum of money is contributed to the city in lieu of taxes. The 10 per cent increase in sewage treated resulted in a 9 per cent increase in revenue

* For last previous extract see This Journal, **28**, 2, 231 (Feb. 1956).

from service charges. Approximately four-fifths of the increased revenue was from industrial users. Although there was an increase in revenue, the expenditures exceeded revenue. The deficit was made up from reserve funds built up prior to the lowering of the sewage service charges in July 1953. The final revenue bonds issued to build the plant in 1936 were to mature September 1, 1956, at which time the utility would be debt free.

Industrial Wastes

Considerable time was spent by plant personnel in continuing an industrial wastes educational program with industry. Most of the industries have cooperated fully regarding the discharge of wastes, now that they have become familiar with the total problem. At no time during the past year was the treatment plant process upset by industrial wastes, although there were occasions when the concentrations of certain wastes exceeded the standards set forth in the sewer ordinance of 1953.

Equipment

Both comminutors are badly worn and allow the passage of coarse materials. Plans have been made to correct this condition. Operation of the grit chambers and primary clarifiers was continuous throughout the year. Some

TABLE II.—Summary of Operation Data for the Jackson, Mich., Sewage Treatment Plant for the Year Ending June 30, 1955

Item	Average
Connected population (est.)	50,000
Rainfall, total (in.)	32.08
Sewage treated:	
M.g.	3,703
M.g.d.	10.15
G.p.c.d.	203
Grit (cu. ft./mg.)	1.04
Sewage analyses:	
Suspended solids:	
Raw (p.p.m.)	184
Settled (p.p.m.)	154
Final (p.p.m.)	14
Reduction (%)	93
B.O.D.:	
Raw (p.p.m.)	143
Settled (p.p.m.)	102
Final (p.p.m.)	6
Reduction (%)	96
Lb. per cap. per day in raw	0.24
Dissolved oxygen (p.p.m.):	
Raw	3.6
Settled	4.1
Final	6.0
Oxygen consumed (p.p.m.):	
Raw	46.8
Settled	42.4
Final	10.0
Organic nitrogen (p.p.m.):	
Raw	7.3
Settled	6.9
Final	3.3
Ammonia nitrogen (p.p.m.):	
Raw	9.1
Settled	9.8
Final	9.8
Nitrite-nitrate nitrogen, final (p.p.m.)	0.0
Aerators:	
Mixed liquor susp. sol. (p.p.m.)	2,200
Sludge index	36
Air used (cu. ft. per gal.)	0.6
Kilowatt hours per m.g.	434
Return sludge (%)	24
Primary sludge:	
Solids (%)	4.8
Volatile solids (%)	58
Solids removed, dry lb./m.g.	1,419.54
Volume (gal./m.g.)	3,225
Digested sludge:	
Solids (%)	9.0
Volatile solids (%)	42
pH	7.0
Dry sludge removed (cu. yd.)	9,460
Gas production:	
Total (1,000 cu. ft.)	15,609
Gas per lb. vol. sol. digested (cu. ft.)	11.3
Cost data ($):	
Cost of operation	89,350.14
Revenue bonds (retirement and interest)	38,744.25
Collection (billings, etc.)	19,654.63
New equipment	9,155.32
Lift stations and sewer maintenance	33,644.49
Insurance	609.20
Taxes	18,000.00
Total	209,158.03
Cost per m.g. (fixed charges included)	47.39
Cost per m.g. (less fixed charges)	29.44

difficulty was encountered with plugged sludge draw-off lines due to an accumulation of sand and grit in the sludge hoppers. The plug valves are badly worn and will be replaced.

The four aerators and three of the four final clarifiers operated continuously. The practice of blowing the aeration plates two or three times each year was continued with satisfactory results. The gear reduction box on one of the clarifiers was sent to the factory for repairs.

Sludge Digestion

Normal operation of the six digesters as two three-stage units was continued. The reduction in gas produced per pound of volatile solids digested has been evident for 8 to 10 years. During the winter months there was not sufficient gas to maintain a comfortable working temperature in the buildings and also to keep the digester temperatures sufficiently high to facilitate digestion. Continuation of this condition, which at present is attributed to the increased use of detergents, will necessitate the purchase of auxiliary fuel. Future plans call for the dewatering and cleaning of the two first-stage digesters.

The original mono-rail system used to remove sludge from the drying beds was sold as scrap. Reinforced concrete ribbon drives through each bed were constructed to replace the mono-rail. Cleaning of the beds can be accomplished just as quickly and there will be a considerable saving in mantenance over the years. The change-over cost only about 1½ times the cost of one painting of the mono-rail system.

Plant Maintenance

The program of preventive maintenance has been largely responsible for the continued uninterrupted operation of the treatment units.

The 5-ft. high chain link fence enclosing the plant grounds was taken down and regalvanized. The posts and top rails were painted with a rust inhibitor and the fence re-erected. All work, except taking the fence down, was done on contract. The total cost was approximately 1¼ times the cost of painting with one coat of rust inhibitor paint.

Use of the plant grounds for picnics and recreational activities has increased. Additional picnic benches and stoves were purchased and placed on the 35 acres of plant park.

Table II summarizes the operation data for the fiscal year 1954–55.

SEWER INSPECTION EXPERIENCE

By Ronald Hicks

Chief Chemist, Auckland Metropolitan Drainage Board, Auckland, New Zealand

The Auckland Metropolitan Drainage Board is responsible for all main sewers and sewage treatment works within a metropolitan district covering some 200 square miles. At the present time, a population equivalent approaching 200,000 is served by a main sewer nearly seven miles in length. The sewage passes through bar screens and some grit is removed, following which it is discharged to Waitemata Harbour. A comprehensive sewerage scheme is now under construction to serve a population equivalent of about 1,500,000 by the year 2000. It is programmed to bring the new scheme into use by 1960, when

Editor's Note—The author took the photographs for this article with an inexpensive 2¼-in. by 2¼-in. Voightlander camera with flash.

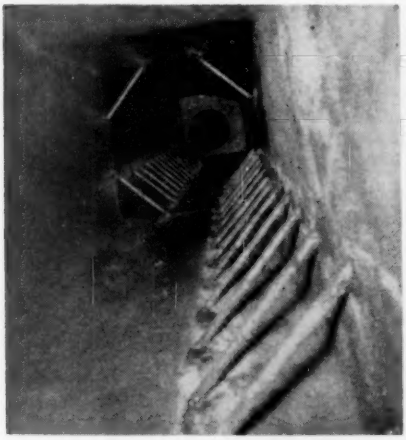

FIGURE 1.—The way down!

FIGURE 3.—Miscellaneous articles (silverware and coins) found in the sewer.

the present discharge into the Waitemata Harbour will cease. The existing main sewer will, however, be retained as a trunk main serving the main city area.

The main sewer was constructed between the years 1909 and 1912. It is egg-shaped for the whole of its length and its dimensions vary from 8.5 ft. by 5.76 ft. at the discharge end to 5 ft. by 3.34 ft. at the upper end. The gradient decreases toward the discharge end from 1:1,700 to 1:3,000.

For various reasons, detailed inspection of this sewer had not been made for many years. By 1953 it became evident that silting was taking place in some sections and that attention was urgently needed. The sewer for the most part serves an area of combined sewers, with the result that frequent surcharging occurs in wet weather. The rapidity of onset and high intensity of local rains result in a rapid increase in flow without much warning. Rainfall is fairly evenly spread throughout the year and no reasonable prediction of "dry weather periods" can be made. Furthermore, high hydrogen sulfide intensities are

FIGURE 2.—Variation in grit deposits.

FIGURE 4.—The start of root penetration.

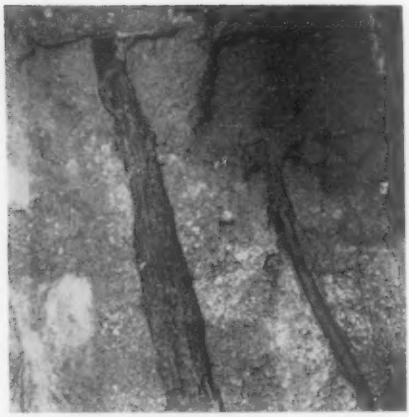

FIGURE 5.—Damage to sewer caused by root growth.

encountered in various parts of the sewer. Flushing from a large tannery, using sodium sulfide as a delapitory, has been practiced for about 30 years at a point 30,000 ft. from the outfall, so that insoluble sulfides were probably mixed with the silt along most of the sewer length.

One of the main difficulties to arise was that access to the sewer was most difficult, manholes being few and far between. For example, between the lengths 23,700 ft. and 35,000 ft., only seven manholes were available, varying in depth between 27 and 56 ft. Of these seven, three did not give direct access to the sewer but led down via side adits. The diameter of the manholes was only 19.5 in.

The first man entering the sewer for inspection was equipped with a fully self-contained oxygen breathing apparatus and was capable of full immersion in water if necessary for about one-half hour. This leader was attached to a stout life line and carried a safety lamp capable of showing the presence of the normal toxic volatile compounds likely to be encountered in sewer air. A rough measurement of the hydrogen sulfide content was obtained by the exposure of large filter papers which had the word "Danger" written on them with a paint brush using either a lead acetate or sodium plumbite solution. The rate of appearance of the word in readable form and the deepening in intensity of the letters against the white background of the otherwise unmarked paper, became a guide to indicate the hydrogen sulfide concentration. Psychologically the rapid appearance of the "Danger" sign, readable even under very poor light conditions, proved very effective and none of the personnel concerned was ever inclined to ignore it.

Even where direct access was available, great care was needed in descending the manholes. Figure 1 shows a typical manhole, 43 ft. deep, with every step greasy. Normally a grating is positioned between the two sets of rungs, but this had to be removed to permit rubble being drawn up in baskets.

Deposition of grit proved quite troublesome; as shown in Figure 2 sudden changes in the amount of grit on the bottom of the sewer frequently led to complete immersion of the inspector. In a distance of 36 ft. the depth of silt varied from 3 ft. to 3 in. The bricks and rubble buried in the fine silt presented a constant obstacle, especially for the unwary, and many a

FIGURE 6.—Complete destruction of the 9-in. by 9-in. concrete sewer blocks.

toe was stubbed. This rubble was lifted out of the sewer by manpower and heaped on the street above the manhole. An interesting collection of miscellaneous articles found among this rubble is shown in Figure 3.

Inspection showed that tree roots, obviously in search of water, had penetrated through the concrete slabs in several lengths of the sewer. The commencement of root growth is shown in Figure 4, and the rapid breakdown of otherwise good concrete when the root has a firm hold is shown in Figure 5. Figure 6 shows how complete destruction of the sewer took place, resulting in damage so serious that a new arched roof had to be provided over a length of approximately 40 ft. Some sewer sections constructed with concrete blocks were in excellent condition and no root penetration was observed.

In addition to immediate local repairs which are now being given attention, nearly 6 miles of sewer will need to be freed from heavy accumulations of grit.

TIPS AND QUIPS

Froth *vs* Foam

From time to time reference is made to the frothing of aeration tanks rather than foaming, although the two words are essentially synonymous in dictionary definition. The term "froth" has purposely been adopted by THIS JOURNAL (**24**, 5, 670; May, 1952) in referring to the aeration tank problem as distinguished from the "foam" problem at sludge digestion units.

Progress Against Pollution

The Ohio River Valley Water Sanitation Commission reports that now 85 per cent of the 3,600,000 population adjacent to the banks of the Ohio have sewage treatment plants in operation or under construction. Thus the Ohio Valley has progressed from three out of every eight persons served by sewers in 1948 to six out of eight in 1956.

Although much remains to be done in this field, the progress has been encouraging. The evidence is summed up in the statistics reported by *Engineer News-Record* which show more than 50 per cent increase in sewage works construction volume in 1956 over 1955. And this, without the newly authorized federal aid.

Automation

The U. S. Bureau of the Census reports that the farm tractor has replaced the horse, and that more farms have tractors than have running water. However, Silas is still using the old path.

Basic Sewage Chemistry

Information, in simple and understandable terms, to help the sewage plant operator in his laboratory will be found in the article "Water and Sewage Chemistry and Chemicals," *Public Works*, October 1956.* If you haven't already appropriated those pages for your ready reference or personal refresher course, it is recommended that you get a copy soon. This revised and expanded article by Kenneth W. Cosens, Associate Professor of Sanitary Engineering, Ohio State University, uses color so that certain colorimetric tests are illustrated as clearly as an actual laboratory demonstration.

Company Safety Booklet

A new booklet, designed to summarize a company safety program for

* Public Works Journal Corp., 200 South Broad St., Ridgewood, N. J.

its employees, has been made available by the Norton Company, Worcester 6, Mass., to supervisory personnel interested in preparing a similar booklet or developing a safety program.

The booklet discusses briefly the causes of accidents and how a safety program operates to eliminate hazards. It explains the employee's responsibilities in reducing accidents and solicits his assistance in providing a safe place in which to work.

Operating Enclosed Electric Switches *

Form the habit of operating an enclosed switch with your left hand. The handle is invariably on the right-hand side, and when operated with the left hand your body will be out of direct line with a flash if one should occur.

1. Stand to the right and at arm's length from the switch box.
2. Take hold of the switch with your left hand.
3. Turn your face away from the switch.
4. Close or open the switch quickly and firmly.
5. If the switch handle is loose, or if it does not operate smoothly for any reason, notify your supervisor or the electrician promptly.

Hospital Wastes

Solid wastes from hospitals are reported to increase from 6.5 to 9 lb. per patient per day when the patient load decreases from 500 to 100 patients. No report was made on what portion of this waste could be ground and disposed of to the sewer system.

* National Safety Council, Instruction Card No. 60.

Pollution Counter

The fisheries people have developed a gadget that counts the fish swimming up or down the stream. Now if someone would just develop a gadget for counting pollution particles going downstream, automation in stream pollution would be well underway.

Poor Sewage Plant!

When an explosion of gasoline vapors blew three sewer lids high into the air the local fire department opened hydrants and flooded sewers in the area of the explosion to flush away the gasoline. The sewage treatment plant was a virtual powder keg for several hours until the gasoline was discharged through the plant and the vapors dispersed.

Falls Hurt

Falls, whether on the job, at home, or in between, account for more accidental deaths than any other cause, with the exception of traffic accidents. Even office workers are prone to fall; more than one-half of all injuries to this class of worker can be attributed to accidental falls.

Falls take a heavy toll of workers, ranking just after handling objects as the greatest source of disabling work injuries. Falls from different heights frequently result in death or serious injury and compensation payments therefore are substantially above those for other accidents.

Don't be a fall guy. Watch your step!

Editorial

THE UNITS OF EXPRESSION REPORT

The printing of a Manual of Practice Subcommittee Report in preliminary form in this Journal is unprecedented in the history of the Federation. Even though this report is the culmination of many years of committee effort, it did not seem ready for final action by the Board of Control.

The tentative report on "Units of Expression" is included in this issue, starting on page 134. You are invited to give your constructive comment and criticism. In this way you will help the Federation make a vital decision which could affect the future activities of all those in the field of sanitary engineering.

Comments to date have ranged from unqualified and enthusiastic approval to absolute rejection. Some have looked upon the suggested changes as being so great that complete conversion to the metric system might just as well be undertaken!

Where you stand in this spread of opinion is squarely up to you. Before submitting your thoughts we urge you to reread the introduction as well as the report itself. We further urge you to give some of the suggested units a trial. If your prime interest is operation, try the simplicity of loadings on treatment units. If it is design, try sizing of units with the direct expressions offered.

The report suggests that we no longer express trickling or sand filter liquid loadings as millions of gallons per acre per day. Instead of this expression, which consists of a volume per unit time divided by an area, the report offers the simple vertical linear rate in *feet per day*. Surface overflow rates may similarly be used in ***feet per hour*** instead of gallons per square foot per day which again is volume per unit time divided by area.

In your hypothetical trial, remember stream flows are given in cubic feet per second by the U. S. Geological Survey. Using sewage flow in cubic feet per day then fits easily into the whole system.

It is interesting to note that the suggested units would eliminate the present confusion of the U. S. gallon (8.33 lb.) with the Imperial gallon (10 lb.) as the use of neither one is suggested.

The Federation is completely mindful of the implications of these suggestions. Included in this awareness is the realization that the Federation cannot bring about the use of these methods by their adoption by the Board of Control. Before a real acceptance could be expected, sanction by the American Water Works Association and the Sanitary Engineering Division of the American Society of Civil Engineers and Federation Member Associations would be necessary. It would seem to be asking too much for consulting engineers to use one set of units for water supply and treatment and another for the system collecting and treating the used water. Another group that would be faced with the same problem is made up of state and interstate agencies dealing with water and sewage problems. Sanction by these groups and general use by the individuals in them would be requirements of full acceptance.

R. E. F.

News and Notes

Of Persons and Activities in the Field of Hydrowastes

Morris M. Cohn, Chairman of the Federation's Sewage and Industrial Wastes Practice Committee, has been named Editorial Director of *Wastes Engineering* and *Water Works Engineering*.

Thorndike Saville, Dean, New York University College of Engineering, for the last 20 years, announced that he will retire with the start of the 1957 fall term.

B-I-F Industries, Inc., has named **Leon H. Chamberlain** as District Engineer for Water and Sewage Sales, West Coast Region, B-I-F Industries, and **Frank D. Brindel** as manager of the Berkeley office of B-I-F Pacific.

Paul Troemper, a Sanitary Engineer with the Illinois Department of Health for 21 years, has resigned to accept the position of District Engineer with the Springfield, Ill., Sanitary District.

W. Allan Moore, of the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, has been elected chairman of the American Chemical Society's Division of Water, Sewage and Sanitation Chemistry for 1957. He succeeds **Dr. J. Carrel Morris** of Harvard University. **Professor H. Heukelekian** has been named to represent this division on the ACS Council; **Professor Robert S. Ingols** will be the alternate councillor.

One of the first civilians to win one of the Secretary of the Army's Research and Study Fellowships is **William H. Wechter**, Chief of the Sanitation Branch, First Army Engineer Section, New York, N. Y. He will study in the field of radiological contamination.

Vinton W. Bacon, Executive Officer of the California State Water Pollution Control Board since activation of the Board in 1950, has resigned to accept a position with the newly organized Northwest Pulp & Paper Association, Tacoma, Wash. Successor to the California position is **Paul R. Bonderson**, Executive Officer for the Central Coastal Regional Water Pollution Control Board at San Luis Obispo since 1950.

American Well Works recently announced the appointment of **Gerald A. Fleet** as its New York District Sales Representative.

Harry E. Schlenz, President of Pacific Flush Tank Company, has been elected president of the Water & Sewage Works Manufacturers Association.

A recent addition to the specialty group of engineers comprising Resources Research, Inc., is **Gilbert V. Levin**, formerly Public Health Engineer and Civil Defense Coordinator for the District of Columbia Department of Public Health.

Harold B. Gotaas will be the new Engineering Dean at Northwestern University, Evanston, Ill. For the past 10 years Gotaas has been Professor of Sanitary Engineering at the University of California, where he held positions as department chairman and director of the sanitary engineering laboratory.

Organizational changes in the City of San Diego Sewerage Division have resulted in the appointment of **Eric V. Quartly** as Superintendent of the Sewerage Division, in charge of sewer maintenance and treatment. Formerly he was Superintendent of the Treatment Division.

Frank A. Butrico, USPHS, has succeeded **Harvey F. Ludwig** as Chief, Office of Engineering Resources, Division of Sanitary Engineering Services.

Dorr-Oliver Inc. continues its expansion program with the formation of a subsidiary in Australia, a new office in Baltimore, Md., and additional plant facilities at Hazleton, Pa.

Armco Drainage & Metal Products, Inc., recently purchased the Pekrul Gate Division of the Morse Brothers Machinery Company of Denver, Colo., and is constructing a new fabricating plant in Denver.

Dr. Baboobhai V. Bhoota of Bombay, India, has been elected to the Board of Directors, Dorr-Oliver (India) Ltd. Dr. Bhoota studied in the United States and is active in sanitary engineering in India.

R. S. Rankin has retired from his position as Director of the Sanitary Technical Division, Dorr-Oliver Inc. His successor is **Fred G. Nelson**, Manager of the Western Sanitary Division, Oakland, California, and a former Director of the Federation.

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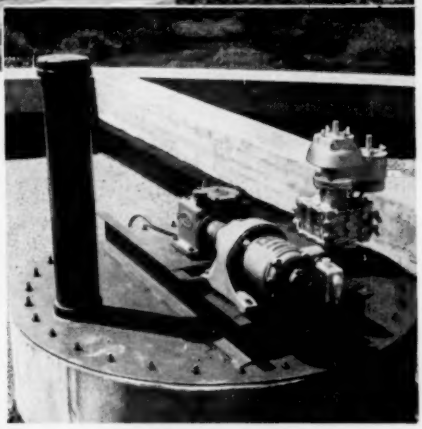

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Proceedings of Member Associations

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 29th Annual Meeting of the Central States Sewage and Industrial Wastes Association was held at the Northland Hotel, Green Bay, Wis., June 20–22, 1956. Registration totaled 183.

Among the interesting papers presented at this meeting were the following:

"Volatile Acids in Digesting Sludge," by Gerald Teletzke, Purdue University, Lafayette, Ind., and G. A. Rohlich, University of Wisconsin, Madison, Wis.

"Expansion of Sewage Works at Indianapolis," by H. D. Tousley, Indianapolis, Ind.

"The Use of Plastics in the Sewage Treatment Field," by Edward H. Bryan, Dow Chemical Company, Midland, Mich.

"Stream Surveys and Preliminary Evaluation of Conditions," by Averill J. Wiley, Appleton, Wis.

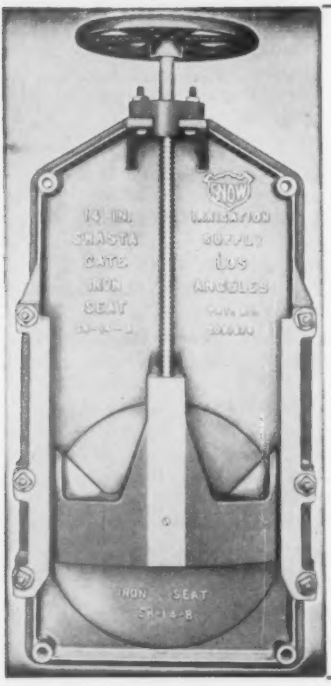
"Industrial Wastes Problem," by N. L. Malcove, Green Bay, Wis.

"Sewage Treatment Problem," by Bruce Stevens, Green Bay, Wis.

Inspection trips were arranged to the Green Bay Metropolitan District Sewage Treatment Plant, the sulfite liquor evaporation and incineration plant of the Marathon Corporation's Northern Paper Mills Division, and to the yeast plant of the Charmin Paper Mills to observe yeast propagation on sugars in sulfite liquor.

The Operators' Breakfast featured a panel discussion. Participants were

(*Continued on page 72a*)



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E. J. Beatty, Urbana-Champaign, Ill., Walter Hogenson, Rochester, Minn., W. W. Mathews, Gary, Ind., and Frank Vilen, Kenosha, Wis.

The Federation's Bedell Award was presented to George J. Schroepfer, Professor of Sanitary Engineering, University of Minnesota.

Officers elected for 1956–57 were:

President: W. E. Ross, Richmond, Ind.

1st Vice-President: A. P. Troemper, Springfield, Ill.

2nd Vice-President: R. W. Frazier, Oshkosh, Wis.

3rd Vice-President: L. H. Smith, Minneapolis, Minn.

Secertary-Treasurer: George F. Bernauer, Madison, Wis.

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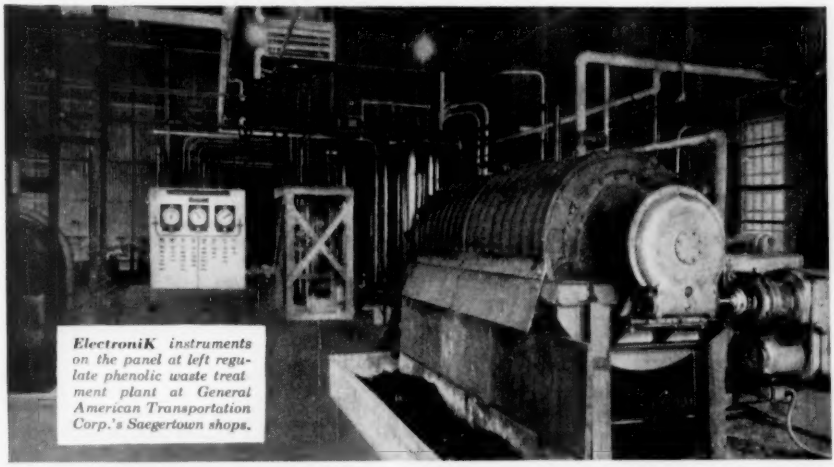

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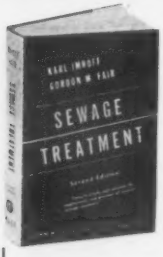

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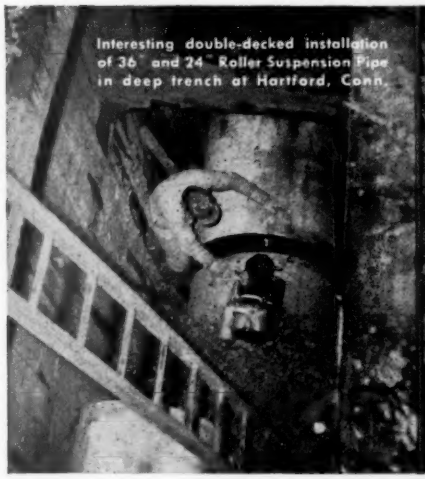

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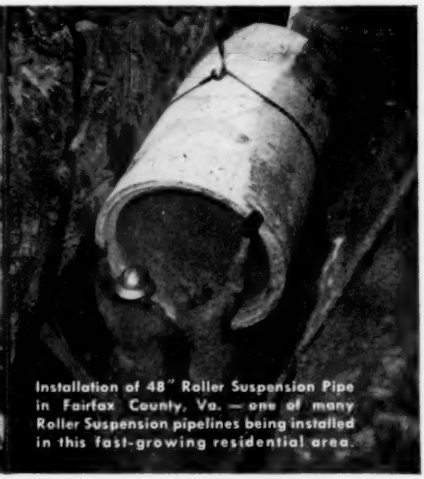

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